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Wastewater Collection System Rehabilitation Techniques for Army Installations

by
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Aging sewer systems can cause serious and expensive problems on Army installations, such as greater infiltration/inflow (I/I). I/I raises the total volume of water, which makes treatment more difficult and costly, may result in fines for exceeding prescribed flow rates, and may cause sewers to overflow.

This report is intended for Facilities Engineers faced with sewer rehabilitation issues. It describes conditions which promote I/I, summarizes several methods for rehabilitating and resealing sewers, reports preliminary test results for a method never before used for sewer rehabilitation in the United States, and discusses the applicability of each method under certain sewer system conditions.

Appendices provide information on current Army sewer systems, on writing specifications for inspection and rehabilitation contracts (a standard, comprehensive Statement of Work [SOW] which can be tailored as needed), and on inspecting rehabilitation work.

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Appendices provide information on current Army sewer systems, on writing specifications for inspection and rehabilitation contracts (a standard, comprehensive Statement of Work [SOW] which can be tailored as needed), and on inspecting rehabilitation work.

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FOREWORD

This research was conducted for the U.S. Army Engineering and Housing Support Center (USAEHSC), and Headquarters, U.S. Army Corps of Engineers (HQUSACE), under Project 4A162720A896, "Environmental Quality Technology"; Technical Area B, "Environmental Design Construction"; Work Unit 055, "Technology for Renovating Army Potable Water Infrastructure." The HQUSACE Technical Monitor was Mr. Bob Ross (CEEC-EB) and the EHSC Technical Monitor was Mr. Tom Wash (CEHSC-FU). Field testing of one technology, the Pipe Insertion Machine, was carried out under Facilities Technology Application Test (FTAT) "Rehabilitation of Sewer Pipes." Mr. Wash was also the Technical Monitor for the FTAT.

The work was conducted as a cooperative effort between the Environmental Division (EN) and Engineering Materials Division (EM), U.S. Army Construction Engineering Research Laboratory (USA-CERL). Dr. R. K. Jain is Chief of USA-CERL-EN. Dr. R. F. Quattrone is Chief of USA-CERL-EM. Dr. E. D. Smith is the leader of the Water Quality Management Team at USA-CERL. The technical editor was Jane Andrew, Information Management Office.

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WASTEWATER COLLECTION SYSTEM REHABILITATION TECHNIQUES FOR ARMY INSTALLATIONS

1 INTRODUCTION

Background

The U.S. Army owns and maintains a network of waste collection systems on installations throughout the world. According to the FY86 Red Book (Volume III, Installations Performance),¹ there is a total of 12,500 mi.* of sanitary sewer mains and laterals, Army-wide, with 10,150 mi. in the continental United States (CONUS). In addition, there are approximately 300 mi. of industrial collection mains, almost all in CONUS. Failures in the collection system can result in excessive costs for sewage treatment, loss of service to portions of the installation, and/or restrictions from outside agencies on Army activities such as new construction. Currently a correction program is initiated only after such problems arise. This crisis management approach can lead to excessive expense. Planned operation and maintenance programs can avoid the expense of open trench replacement and maintain system integrity, whereas open trench work is the only method for rehabilitating a completely collapsed sewer line.

Wastewater collection systems on Army installations receive little attention until a problem arises, because most components are out of sight. They are often allowed to deteriorate until they cause extra expense or cease to function. Further, deterioration allows excess water to enter the system, causing unnecessary expenses when Army installations pay for wastewater disposal based on the quantity of raw wastewater produced (e.g., cost is in dollars per thousand gallons treated), or when the flow exceeds wastewater disposal flowrate permits, resulting in state-imposed fines.

Wastewater collection systems, or sewers, are sets of pipes, manholes, and pumping stations constructed below ground which are used to collect domestic and industrial wastewater. Pipes follow the general contour of the land, using gravity to collect the wastewater. The need to maintain a certain slope to avoid deposition of solids dictates that some sewer lines be deeply buried, ranging from less than 10 ft to greater than 35 ft. In areas where pipes are very deep, a pumping station may be used to lift the wastewater back near the surface, or it may be used to carry the water over a ridge between natural drainage basins.

A major problem experienced by deteriorated wastewater collection systems is infiltration--water leaking into the wastewater collection system through cracks in the collection system pipes, manholes, and building laterals. The U.S. Environmental Protection Agency (USEPA) established criteria for control of infiltration and inflow (I/I) in sanitary sewer systems in which the I/I must be reduced as much as economically possible. Inflow is relatively pure water which is deliberately diverted to the sanitary sewer system through mechanisms such as connection of roof and/or basement drains to the sanitary sewer system.

¹Facilities Engineering and Housing Annual Summary of Operation Report, Fiscal Year 1986, Vol III, "Installations Performance" (Office of the Assistant Chief of Engineers, Department of the Army, 1986). For official use only.

*Metric conversion factors are provided at the end of the report.

The tradeoff in I/I reduction is between (1) rehabilitating or reconstructing the sewers and manholes and (2) building sufficient capacity into the sewage treatment plant to treat the peak flows experienced during storms. Dilute wastewater is also more difficult to treat, resulting in the same concentration in the effluent, but exceeding mass loadings to streams due to the higher flows.* In addition, infiltration intercepts precipitation which should go to recharge the groundwater. Infiltration can also cause downstream sewers to be hydraulically overloaded and to overflow at manholes.

Army installations outside the continental United States (OCONUS) which discharge into combined storm/sanitary sewers have significant problems with hydraulic overloading of the sewers. Hydraulic overloading can arise from I/I, installation of new building connections without corresponding expansion of collection system capacity, and/or paved areas leading to greater surface runoff. Hydraulically overloaded sewers can cause overflowing sewers, excessive costs for sewage treatment by volume, and, perhaps most importantly, a ban on new construction.

Objective

The objective of this report is to provide personnel responsible for maintaining Army wastewater collection systems with (1) an overview of the conditions that result in deterioration, (2) a summary of the rehabilitation techniques that can be used to solve the problems deterioration causes, (3) a description of a test of a method which has not previously been evaluated, and (4) guidelines on selecting an appropriate method and on insuring the quality of the work.

Approach

To assess the effectiveness of sewer rehabilitation techniques in correcting wastewater collection system deterioration, the technical literature was surveyed. Manufacturers' literature was reviewed to determine the appropriateness of processes being marketed. Army installations were surveyed by letter to determine the materials used in their sewer systems and the extent of infiltration/inflow work which has occurred. Under an FTAT program, a new process for replacing pipe (including upsizing) without open trench work, called the Pipe Insertion Machine, was reviewed and tested at an Army installation. This process was developed in the United Kingdom, and the Army test represented the first trial of this process for sewer rehabilitation in the United States. The results of the field test are summarized here. General cost estimates were taken from the literature to determine the feasibility of various processes under differing economic and field construction conditions. A sample Statement of Work (SOW) with notes and suggestions and a set of inspection checklists are given in the appendices.

Scope

The techniques described in this report apply to CONUS and OCONUS Army installations responsible for construction, maintenance and/or repair of wastewater collection systems.

*Permits are written based on concentration (e.g., mg/L) and mass (e.g., lbs/day). If the concentration limit is met, but the normal flow is exceeded, then the total mass/day, which is the concentration times the flow per day, exceeds the mass load limit.

Mode of Technology Transfer

It is recommended that the findings and recommendations of this study be published in an Engineer Technical Note. The results may also impact Technical Manual (TM) 5-814-1, *Sanitary and Industrial Wastewater Collection—Gravity Sewers and Appurtenances* and TM 5-666, *Sewage Treatment Plants and Sewer Systems at Fixed Installations*.

2 SEWER CONSTRUCTION MATERIALS

The problems a sewer system experiences and the rehabilitation techniques used depend in part on the construction materials, so they are discussed here briefly.

Wastewater collection systems have been traditionally constructed of a wide range of materials, including the following:

- Asbestos-cement
- Bitumized fiber (laterals)
- Brick and mortar
- Cast iron (force mains)
- Concrete
- Steel (force mains)
- Thermoplastics
 - Acrylonitrile butadiene styrene (ABS)
 - Polyethylene (PE)
 - Polyvinyl chloride (PVC)
 - Reinforced plastic mortar (RPM)
 - Styrene rubber
- Vitrified clay.

The choice of pipe material at a particular site depends on many factors. Brick and mortar have been used in the past primarily in the largest sewers. Asbestos-cement (also known under the trade name Transite) and concrete are the next largest size of sewer in common use. Vitrified clay, and more recently, thermoplastics, are used in the smaller size range. Bitumized fiber is used in small diameter piping such as that used for building laterals. There is considerable flexibility in choice of material and size, and selection can be influenced by local availability.

Army installation Directors of Engineering and Housing (DEHs) in the United States were surveyed to determine the materials used in sanitary and stormwater systems. The survey form is shown in Appendix A, and the results of the survey are given in Appendix B. Twenty-four installations responded, of which 22 were able to estimate the percentages of the various pipe materials. The results are summarized in Table 1 in terms of percent of material by type.

Table 1

Sewer Construction Materials from Results of Sewer System Survey

Material Type	Percent of Total Reported
Cast iron	3.5
Vitrified clay	56.5
Concrete	21.6
Asbestos-cement	4.3
Polyvinyl chloride	6.0
Acrylonitrile butadiene styrene	2.9
Galvanized steel	0.4
Wood	0.1
Other	4.7

"Other" included a very small amount of brick and mortar construction, as well as materials used in sliplining with polyethylene pipe or installing Insituform* thermally-cured, resin-felt liners during rehabilitation. Galvanized steel and wood may represent small sections of stormwater collection sewers (the survey did not differentiate between storm and sanitary sewers). The distribution observed represents only 18 percent of the sewer pipes maintained worldwide by the Army, but should be representative of CONUS fixed Army installations. Cast iron is generally used only for force mains, and the data indicate that cast iron is only a small percentage. Vitrified clay and concrete comprise the bulk of the sewers on Army installations, as expected. Polyvinyl chloride and other plastics will increase in percentage in the future as Army installations replace and/or upgrade their existing systems.

*Insituform is a trademark of Insituform of North America, Inc.

3 CAUSES OF SEWER SYSTEM DETERIORATION

Underground piping systems are subject to a number of forces which contribute to their deterioration. The surrounding soil contributes stresses associated with corrosion, weight, and frost heave. Surface loads are transmitted to the pipe by soil, depending on the depth of the pipe. Groundwater can place an upward stress on empty pipes. Lowering the groundwater table by diverting surface runoff to stormwater systems can cause differential settling. Temperature variations cause the pipe to expand and contract over the seasons. The transported wastewater can contain corrosive materials, and some corrosive substances are created in the pipe environment. Roots grow through cracks and joints, causing sewer blockages and aggravating the cracks.

Chemical Causes

A well documented corrosion problem in sanitary sewers, "crown corrosion"² is the result of microbial action. In areas of the pipe in which wastewater can stand, due to insufficient slope, obstructions, displaced joints, etc., the water is quickly exhausted of oxygen. Under these conditions, certain bacteria can use other compounds as a substitute for oxygen, depending on their availability and the energy yield from them. Nitrate is converted to nitrogen gas, sulfate is reduced to sulfide, and carbon dioxide is reduced to methane. The major problem for sewer pipes is related to the conversion of sulfate to sulfide.

In pooled wastewater, which has insufficient turbulence to rapidly transfer oxygen, sulfate is converted to sulfide in the absence of oxygen, ultimately resulting in the production of toxic hydrogen sulfide gas. The gas diffuses into the air overlying the pooled water. Hydrogen sulfide can be aerobically oxidized to corrosive sulfuric acid by species of *Thiobacillia*. The air above the water and the thin films of condensed water on the crown of the pipe provide an excellent aerobic environment for the sulfide-oxidizing *Thiobacillia*. In these thin condensate films, the buildup of sulfuric acid creates a strongly corrosive environment which attacks the sewer pipe at the crown, thus the designation "crown corrosion." Figure 1 shows the conditions which lead to sulfuric acid production.

Physical Causes

The physical forces on sewer pipes (overburden, groundwater buoyancy, frost heave, differential soil settling) result in stress fractures, crushed pipes, and displaced joints. Corrosion from chemically aggressive wastewaters, products of microbial degradation, or soil-side environmental conditions degrade the material, causing cracks and holes directly, or weakening the pipe so much that the physical forces cause it to break or collapse. Small breaks in the system will not cause apparent failure but can lead to potentially more costly failures.

The first type of failure in a wastewater collection system is related to infiltration of groundwater and surface runoff into the sanitary system. Infiltration can dramatically increase the quantity of wastewater which must be treated when precipitation occurs. This increase may require expansion of sewage treatment capacity (with associated capital costs) or may cause violations of wastewater effluent permits under the National

²John W. Clark, Warren Viessman, Jr., and Mark J. Hammer, *Water Supply and Pollution Control* (International Textbook Company, New York, 1971), pp 383-4.

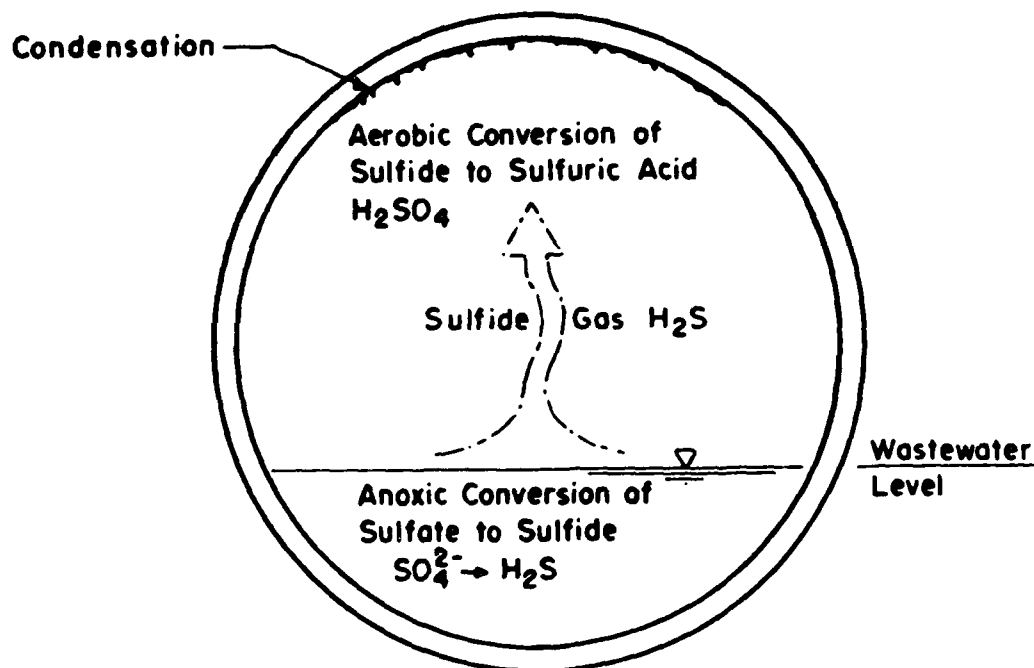


Figure 1. Microbiological mechanism responsible for crown corrosion.

Pollutant Discharge Elimination System (NPDES). Engineer Technical Note 10 contains additional information.³

A second major problem associated with small breaks in sewer pipes is washout of soil around the pipe, causing the ground surface to collapse. The mechanism is shown in Figure 2. An opening above the sewer, due to a corroded crown, allows soil to fall into the pipe, where it is washed away. Small-diameter pipes may be rapidly clogged because the flow rate is too low to remove the solids. Over time in larger pipes a soil cavity develops which can collapse, causing surrounding soil to subside. A spectacular case occurred in 1957 when a trunk sewer failure caused a large street to collapse.⁴

³Engineer Technical Note No. 10, "Current Sewer System Infiltration and Inflow (I/I) Management Techniques and Requirements for Excessive Flow Detection, Analysis and Correction" (Department of the Army, Office of the Chief of Engineers, Facilities Engineering Division, 27 April 1982).

⁴R. Sandaas and M. C. Dirks, "Rehabilitation Planning Design, Construction and Maintenance of the Metro Sewerage System in Seattle," presented at the American Society of Civil Engineers (ASCE) Spring Convention, Seattle, WA, April 1986.

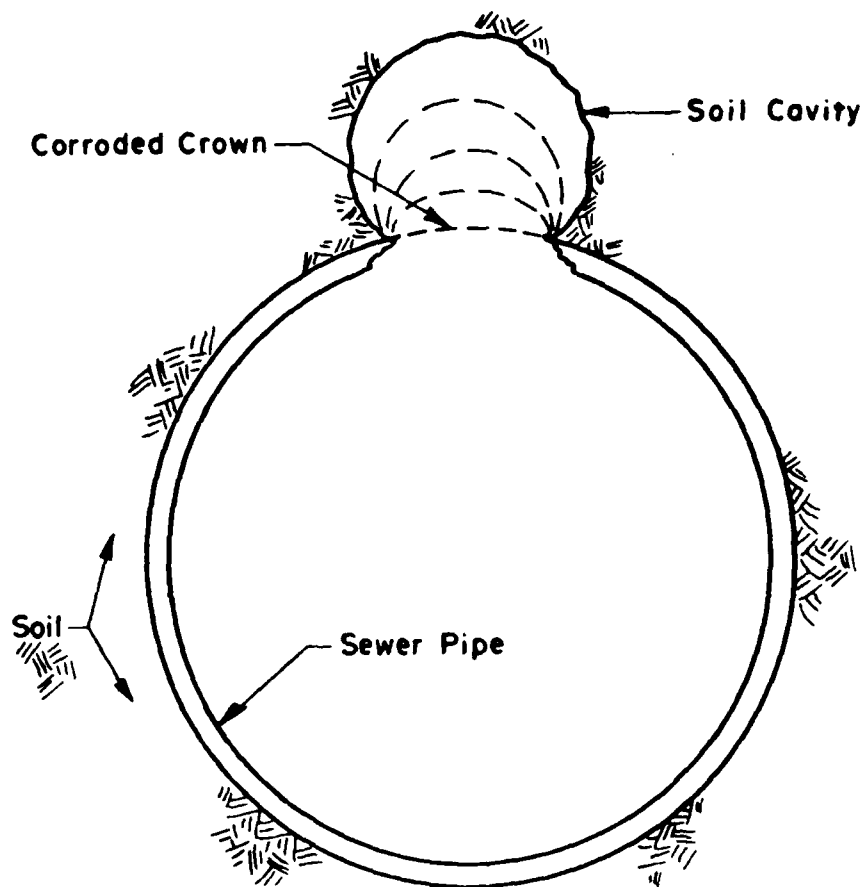


Figure 2. Mechanism of void formation after corroded crown collapses. Soil above pipe slowly falls into the pipe and is carried away by wastewater, allowing the void to grow.

4 SEWER SYSTEM REHABILITATION/REPLACEMENT

Several techniques are available which can rehabilitate sewer systems and bring them into acceptable working condition. The choice of technique may depend on the circumstances which led to the sewer system's problems. Systems which have excessive infiltration/inflow can be rehabilitated by one of several sealing methods if the source of infiltration is cracks in an otherwise structurally sound collection system. Liners can be inserted in systems which have excessive problems with cracks. These liners reduce the pipe cross sectional area, but tend to have less friction losses, therefore vendors claim that the hydraulic capacity does not decrease, and may even increase. Systems which are hydraulically overloaded from sources other than infiltration/inflow cannot be substantially improved by lining or sealing techniques. Replacement can be accomplished by open trench construction, or by destroying the pipe in place and inserting a new pipe using the Pipe Insertion Machine.

The techniques to be discussed in this report include:

- Grouting
- Cement Lining
- Sliplining
- Insituform
- Impact moling
- Open trench reconstruction.

The first four techniques have been reviewed extensively in recent publications⁵ and will only be briefly described here. Impact moling is a newer method under development in the United Kingdom which has been used extensively in the gas industry. Over 500 km (300 miles) of gas mains have been successfully replaced by this method, and it is now commercially available for sewer replacement. The U.S. Army Construction Engineering Research Laboratory (USA-CERL) has conducted a successful test of this technology at Fort Belvoir, VA, which was also the first time this technology has been used for sewer replacement in the United States. Open trench reconstruction is identical to new construction except that it may be possible to reuse the existing manholes.

Grouting

Infiltration which occurs at joints and cracks can be controlled by sealing them with chemical grouts. Locations which require grouting can be identified using closed-circuit-television inspection. The sewer lines must be cleaned of debris and protruding

⁵Thomas I. Simmons and Associates, *Insituform and Other Sewer Rehabilitation Techniques*, EPA/600/2-85/132 (USEPA, November 1985); *Existing Sewer Evaluation and Rehabilitation*, American Society of Civil Engineers Manuals and Reports on Engineering Practice No. 62 and Water Pollution Control Federation [WPCF] Manual of Practice No. FD-6 (Lancaster Press, Inc., Lancaster, PA, 1983; *Utility Infrastructure Rehabilitation* (Department of Housing and Urban Development (HUD), November 1984).

roots prior to the television inspection. This method of repair is most common for spot repair, and a number of grouts are available. The Engineering and Housing Support Center (EHSC) has developed standard Statement of Work (SOW) documents for inspection and rehabilitation of sewer lines which include specifications for grouts and television inspection. These standard SOW documents are included with this report as Appendix C. In general, grouts have to meet the requirements of the American National Standards Institute (ANSI) (in particular, ANSI Standard A118.3-1968, Epoxy Mortar) or the American Society for Testing and Materials (ASTM) (in particular, ASTM Standard C476-71, Mortar and Grout for Reinforced Masonry). The EHSC Point of Contact for these documents is Mr. Tom Wash, CEHSC-FU-S.

The EHSC documents detail the elements of this technique in the work statements. Grouting may be done manually or by remote control. The sewer pipe must first be cleaned to remove root intrusion and debris. Generally, the process involves locating suspected joints and cracks using closed-circuit television (or manual inspection in larger systems), testing these points by sealing off the pipe with an inflatable packer and pumping air into the sealed section, pumping grout into sections which fail the air test, and then retesting after the grout has set to determine if the joint had been sufficiently sealed. This procedure lends itself to situations requiring minimal repair and is most effective in sealing pipes which are otherwise in relatively good structural condition. However, grouting has been found ineffective against longitudinal cracks.

Chemical grouts include acrylamide gel, acrylate gel, urethane gel, and polyurethane foam. The choice of one type over another depends on the type of defect being repaired, handling characteristics, toxicity, and cost. The type of defect being repaired affects the choice of grout depending on whether there is a substantial void outside the defect. Gel grouts will penetrate the crack and fill a void, whereas foam grouts will not. Questions of handling characteristics and toxicity should be left up to the contractor, but installations should also be familiar with these characteristics for their own use in spot repairs. It is generally advisable to utilize grouts of minimum toxicity and minimum handling problems at installations which have only limited need for grouts, because personnel would not use them frequently enough to become familiar with their application and use. The importance of cost depends on the experience of installation personnel: if they are expert at using all types of grout, the least expensive appropriate material should be used; if they are inexperienced, ease of use should be the primary consideration.

Gel grouts are resistant to most chemicals found or produced in sewer lines, but their resistance to byproducts of industrial activities unique to the Army should be considered before a decision is made. The manufacturer should be asked about industrial applications, and should be given a checklist of chemicals which may be disposed of into the sewer line. Gels are susceptible to dehydration and shrinkage cracking, but such problems can be reduced by using chemical conditioners such as ethylene glycol. Acrylamide gel is significantly more toxic than acrylate polymer or urethane gels. Urethane gel uses water as a catalyst, thus special care must be taken to eliminate contact with water. For an occasional user, acrylate polymer is the least difficult to use from a toxicity and handling point of view.

Foam grouts are difficult to apply and more expensive than gel grouts. They can expand up to 12 times their initial volume in an unconfined environment. They are catalyzed by water; thus they must be kept out of contact with water prior to application. They foam on reaction with water, expanding into cracks in the pipe. Foam grouts require significantly longer curing times than gel grouts. Despite these disadvantages, they may be suitable where there are large external voids or porous granular material around the pipe which would require large quantities of a gel grout, or where there is high external pressure.

Remote grouting is accomplished from manhole to manhole using mechanical equipment (Figure 3) including:

- Sealing packer and TV camera assembly
- Manhole roller assemblies
- Grout, catalyst, and air lines
- Winch
- Control and chemical storage truck.

The automatic equipment for grouting and testing was designed to operate manhole to manhole, with one setup operating in two directions from one manhole. Also, the need for remote operation which does not disturb sewers on less accessible private properties (i.e., behind fences and buildings) led to the development of systems which could be operated over a two manhole distance (normally <800 ft) by moving only the winch.

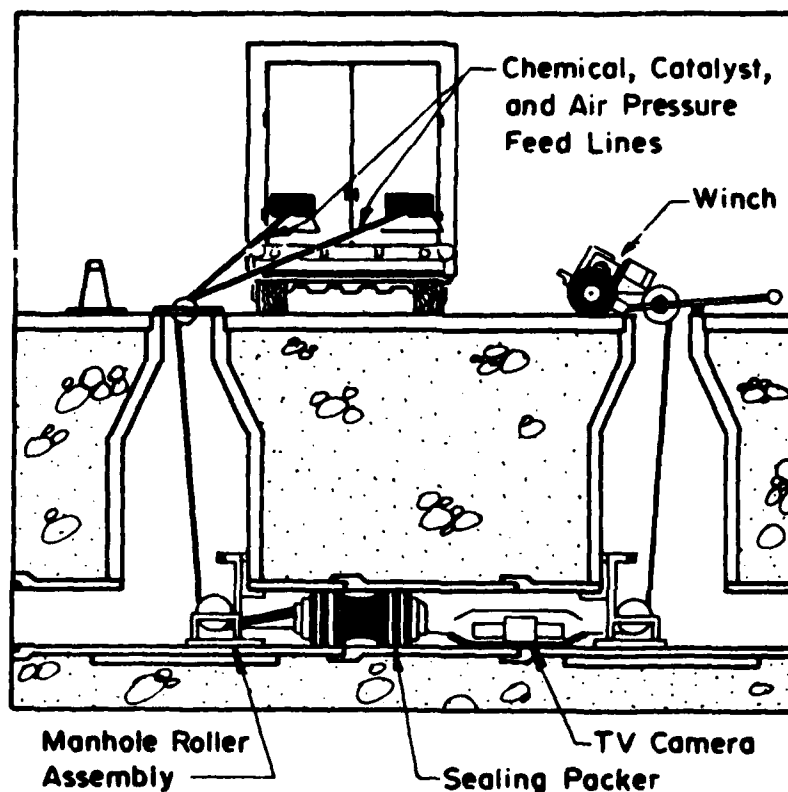


Figure 3. Typical grouting procedure showing sealing packer with ends inflated to seal a joint. (Source: *Utility Infrastructure Rehabilitation* [Department of Housing and Urban Development, November 1984].)

The equipment is usually set up over a manhole and requires one lane of traffic for a parked truck plus operating area (30 ft total) as well as a smaller area determined by the size of the winch unit. All equipment remains at ground level except roller assemblies and the sealing packer. Excavation is not required. The winch is used to move the packer, while the camera is used to locate leaking joints and position the packer. The sealing packer has inflatable ends, shown expanded in Figure 3. The expanded packer seals off the sewer pipe on either side of a crack or leaking joint. The joint or crack is tested by air pressure; if it fails the test it is grouted. The procedure for testing a joint in this way is described in Appendix D under grouting. It generally requires pressurizing the area sealed by the packer to a stable pressure of approximately 3.5 pounds per square inch (psi) and then observing the pressure drop. If the pressure drops 1 psi in less than 30 seconds, the test is failed and the joint or crack must be resealed.

Grout is injected and forced into the joint or crack by inflating the center section of the sealing packer, shown deflated in Figure 3. After the grout has been injected, the sealing packer is moved to the next suspect point using the winch. The repair will then be rechecked using the air pressure loss test after the grout has cured.

Figure 3 shows grouting under ideal conditions with an apparently straight pipe, clear access through the manholes, and no sewer bypass lines. However, it is also easy to imagine conditions under which remote grouting would not function. The packer must have a clear path through the sewer pipe; thus, severely offset joints and crushed pipes will make it impossible for the sealing packer to pass. The line may or may not require bypassing because the inflation/deflation cycle under ideal conditions is short. The requirement for bypassing occurs only in areas with large tributary flows and/or pipe section requiring excessive time to grout.

Figure 4 shows manually controlled repair in accessible sewers. Manually placed sealing rings can be used as shown in Figure 4, or grout can be injected through holes drilled into a pipe joint or through the pipe next to the joint. Manual grouting can also be used to seal joints at manholes.

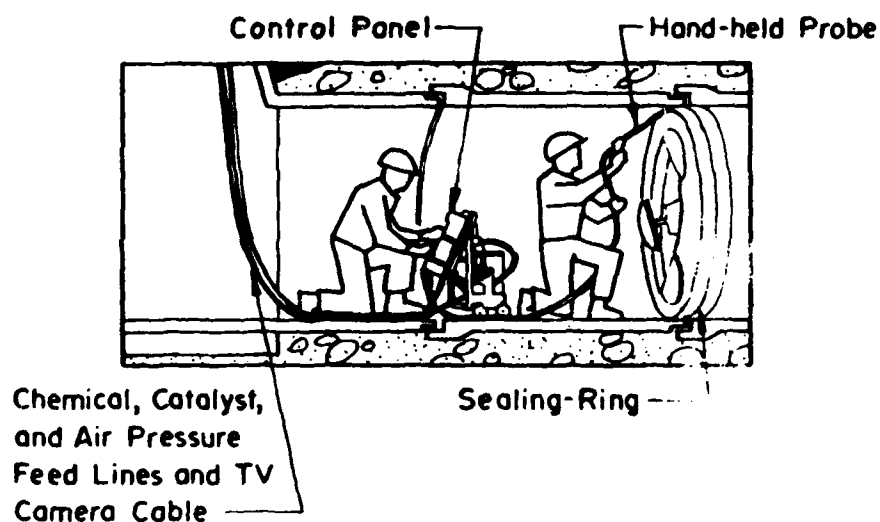


Figure 4. Manned-entry chemical grouting. (Courtesy of Cherne Industries, Inc.)
(Source: *Utility Infrastructure Rehabilitation* [Department of Housing and Urban Development, November 1984].)

Grouting does have some limitations and inconveniences. Cold weather causes problems with delivery and curing. The viscosity of grout increases at low temperature to the point that the individual chemicals cannot be pumped through the bore holes in the packer unit. Moderately low temperature can restrict the distance over which the grout can be pumped. Cold weather also retards the chemical reaction which occurs during curing. Also, sewers large enough to admit people may pose safety problems associated with hydrogen sulfide and lack of oxygen, and precautions such as testing for gas concentration and providing self-contained breathing units may be required. The grouting materials are also toxic and present a safety hazard.

Grouting is often the least costly method which can be employed on a one-time basis. It can be accomplished with minimal traffic delay and no excavation. On the other hand, it does not provide substantial resistance to regrowth of roots through cracks and joints, nor does it provide structural stability to failed pipe sections. Thus, there is a tradeoff between periodic grouting and a more permanent solution such as sliplining, using Insituform, or reconstructing the lines with continuous pipe materials.

Cement Lining (Shotcrete)

Cement lining is most often associated with potable water lines, but it is occasionally used in larger diameter sewers which have undergone severe structural damage. An advantage of cement lining is that it can be used with cage-like reinforcement which is installed in the interior of a pipe. This technique is referred to as shotcrete or gunite, and is a mixture of sand, cement, and water applied using air pressure.

This technique is usually limited to man-entry* sewers in which workers can reach the damaged areas to prepare the pipe section and install the reinforcing cage. This has limited its application to sewers in excess of 36 in. in diameter. The minimum thickness of shotcrete applied is usually 4 in., but thicknesses of up to 12 in. in conjunction with reinforcing steel have been used to correct serious structural problems. Shotcrete reduces cross-sectional area and introduces contraction and expansion joints which can seriously reduce the hydraulic capacity of a pipe.

The application of shotcrete requires a time-consuming construction effort in which the pipeline must be cleaned and prepared by removing or repairing discontinuous surfaces where the existing pipe is displaced at joints or has severe cracks. This provides a smooth surface for application. The reinforcement is constructed, then the shotcrete applied and cured in a moist environment for up to 7 days.

The advantages of this process are that it can be accomplished with little or no excavation, it can reinforce the structural integrity of a pipeline, and in noncircular pipes (e.g., egg shaped pipes) it reduces the capacity less than pipe insertion does. The disadvantages are the requirement for complete diversion of flow and shutoff of services during construction, longer periods (up to 7 days) of lost service, and loss of hydraulic capacity due to loss of cross sectional area. More information on this process can be found in the HUD report.⁶

*The male pronoun is used for convenience; it refers to both genders.

⁶Utility Infrastructure Rehabilitation.

Sliplining

This rehabilitation technique involves pulling or pushing a new pipe into an existing sewer. The sewer must first be cleaned and proved capable of accepting the liner. The proving process involves dragging a pipe section through the sewer to insure that displacements at joints are sufficiently small to allow the liner to pass.

Many types of pipe material have been used in sliplining. Table 2 lists several of these materials and the associated American Society for Testing and Materials (ASTM) standards. There have been limited applications where a metallic pipe has been inserted in noncircular sewers, resulting in large losses of cross-sectional area, but the method did not require open trench construction. However, the most common type of sliplining involves inserting a flexible plastic pipe into a circular sewer. The loss of cross sectional area depends on the maximum size pipe which can be inserted, based on the proving process described above.

The following paragraphs briefly describe each sliplining material.

Extruded Polyethylene. This is the most common type of sliplining material. It is available in standard lengths of 40 ft and in diameters from 2 to 48 in. The material is quite resistant to acids, bases, and other materials common in sanitary sewage. It is susceptible to damage from nonpolar materials such as gasoline, oils, organic solvents, etc. The nonpolar materials can be absorbed by the polyethylene, causing it to swell and soften. However, these nonpolar materials are usually sufficiently dilute in wastewater to be harmless to the liner. In applications which would expose the liner to nonpolar compounds, such as a collection system designed to carry primarily industrial wastewater to an industrial waste treatment plant, the compatibility of all possible compounds with the polyethylene should be considered. Manufacturers should be contacted to determine compatibility.

Table 2
Sliplining Materials and Standards

Material	ASTM Standards
Extruded polyethylene	D1248, D3350*
Spiral ribbed polyethylene	D1248, D3350
Extruded polybutylene	D2666, D3000
Reinforced plastic mortar	D3262
Reinforced thermoset resin	C4184
Cement lined ductile iron	A746
Polyvinyl lined ductile iron	A746

*The most recent editions of these standards can be found in the current year's edition of the *Annual Book of ASTM Standards*.

Spiral-Ribbed Polyethylene. This is a modification of polyethylene which has the ability to adjust load-bearing capacity of the pipe. The load-bearing capacity of this polyethylene pipe is related to the strength and spacing of the reinforcing ribs, as well as to the pipe wall thickness. It is available in diameters from 12 to 144 in., thus covering a wider range of applications than extruded polyethylene. The structural support from the ribbing allows the wall thickness to be less; thus, the loss in cross-sectional area and carrying capacity may be less in some applications than for extruded polyethylene.

Extruded Polybutylene. This alternative to polyethylene is stronger and is less affected by temperature. It is similar in stiffness and chemical resistance to extruded polyethylene.

Reinforced Plastic Mortar Pipe. This is an alternative to polyethylene pipe which is manufactured by a thermosetting process in which strands of fiberglass are saturated with resin and combined with sand to produce the pipe. It is available in standard lengths of 20 ft and in diameters from 18 to 66 in.

Reinforced Thermosetting Resin. This is similar to reinforced plastic mortar, but no sand is added during manufacturing. It is available in standard lengths up to 80 ft, and in sizes from 4 to 192 in. This type of pipe covers a wider range of sizes than does reinforced plastic mortar pipe.

Ductile Iron Lined with Cement or Polyvinyl. This material is much stronger than the plastic insertion materials and is substantially more expensive. Unlined ductile iron would suffer severe corrosion in a sewer system, thus lining is mandatory. In addition, sewers which have experienced severe corrosion should be lined with the plastic polyvinyl rather than cement, because the acids from sulfate reduction can dissolve the cement lining. The strength of ductile iron allows longer lengths to be pushed into an existing sewer. An article describes pushing a pipe for one mile in sewer rehabilitation work in Fairbanks, AK.⁷ The strength also almost eliminates concern for post insertion collapse, which can occur with thermoplastics. It is available in diameters of 4 to 60 in., and comes in lengths of 18 ft. Its major drawback is the cost.

Sliplining Construction Methodology

The pipe is prepared for insertion by butt fusion welding at the surface for polyethylene and polybutylene, or assembled in a trench for the other materials. The size of the trench is determined either by the pipe segment length and pushing machinery size or by the flexibility of the pipe for continuous, welded material. The insertion trench for continuous, welded pipes should be on the order of five times the sewer depth. A conical nose cone should be attached to the leading end of the pipe to help negotiate irregularities in the pipe.

As with grouting, the sewer must be cleaned to remove roots, debris, and other obstructions. The new sewer lining is pulled or pushed into the existing system from entry trench to manhole. Table 3 shows the common method of installation based on liner material. For construction using the pull method, the stressed polyethylene expands radially and contracts longitudinally when the tension is released. This takes time, but no hard and fast rule is available to specify the time required. (One rule is given in ASTM deleteee

⁷A. Soast, "Failed Sewer Saved by Jacking Pipe Through It," *Environmental News Record*, April 2, 1987, p 22.

Table 3

Common Insertion and Joining Methods for Various Liner Materials

Material	Most Common Insertion Method	Joining
Extruded Polyethylene	Pull	Heat Fusion
Spiral-ribbed Polyethylene	Push	Bell and Spigot
Polybutylene	Pull	Heat Fusion
Reinforced Plastic Mortar	Push	Bell and Spigot
Reinforced Thermosetting Resin	Push	Bell and Spigot
Ductile Iron	Push	Bell and Spigot

(Source: *Utility Infrastructure Rehabilitation* [Department of Housing and Urban Development, November 1984].)

Standard F-585-78,⁸ which states that the elongation from pulling will be recovered in a time equal to the time required for insertion.) Additionally, pipe which was warm on the surface (in the sun) may experience temperature-related contraction at a rate up to 1 in. per 100 ft per 10 °C. Grouting should not occur until the pipe "stabilizes," according to ASTM F-585-78. In contrast, St. Onge recommends grouting and sealing immediately after insertion.⁹ The HUD report does not mention time for stabilization.¹⁰ The conservative approach would be to allow at least as much time for contraction as was required for insertion.

Jefferson Proving Ground has experienced problems with lining which may be related to seasonal expansion/contraction of the lining. The lining has been observed to be pulled back several inches from the manhole, and the water flowed through the annular space outside the lining, into the manhole, and then into the wastewater collection system, negating the effects of sliplining. It appeared to occur seasonally, so that regrouting was not effective. The most severe problem occurred in one section which had been lined with a continuous section of approximately 1500 ft. This suggests that there was sufficient temperature-related contraction and expansion, caused only by the minimal seasonal changes in temperature, to render the sliplining ineffective. Solutions to this problem could be (1) placing an expansion joint at the manholes, allowing a pipe to move independently of the manhole, (2) fixing a plate on the end of the liner pipe and attaching the plate to the manhole, (3) limiting the allowable length of continuous pipe which can be installed, or (4) grouting the entire annular space.

The concept of an expansion joint has been developed to the point of a specification by Kenneth Morin of the Chesapeake Division, Naval Facilities Engineering Command (NAVFACENGCOM). The concept is based on a technique developed in Napa Valley, CA by Richard Shank of the Napa Sanitation District. The technique involves excavating at each manhole to expose an 18-in. stub of the existing sewer pipe and installing a flexible

⁸ *Annual Book of ASTM Standards* (ASTM, 1978).

⁹ H. St. Onge, "Relining: The Flexibility of Inserting Pipes into Existing Sewers," *Canadian Water Resources Journal* (1984), Vol 9, No. 3, p 58.

¹⁰ *Utility Infrastructure Rehabilitation*.

coupling to seal the connection and prevent inflow at the manholes. The specifications from Section 02727 of the NAVFACENGCOM specification for sliplining which are related to the flexible coupling installation (subsections 2.1.1.4, 3.1.2, 3.1.5, 3.1.5.1, 3.1.5.2, 3.1.5.2.1, 3.1.6, and 3.1.9) are included in Appendix E. Items pertaining to the use of the flexible coupling are underlined.

By incorporating these specifications into existing Corps of Engineers specifications (changing the numbers and reference sections), this infiltration control technique can be included in Army renovation. Figure 5 is a schematic diagram of the installation procedure. The point of contact for further information on this process is Kenneth Morin, COMM 202-433-3760, AV 288-3760.

Grouting the annular space can serve several purposes. If the structural damage to the existing pipe is severe, and/or there are voids above the pipe, the grout would transfer structural loads evenly to the new pipe and fill voids. Otherwise, uneven loads could cause the liner to collapse. Grouting would also seal the existing pipe such that it cannot carry water to manholes, allowing it to reenter the sanitary system if the liner seal at the manhole fails.

If complete grouting is not specified, the pipe should be grouted where it enters the manhole. Service connections must be dug up individually, after shrinkage has stopped, and reconnected with a heat fused or strap-on polyethylene saddle. The insertion pit must then be backfilled and the section underlying the pit must be replaced by conventional open trench techniques. Alternatively, the new pipe can be pulled into the far manhole to the extent possible, then cut at the insertion pit and dragged back into the near manhole, leaving 6 to 8 in. of pipe extending into the manhole if possible.

Insertion of a new sewer lining avoids the need for total open trench work, but a large pit must be dug to allow the pipe to be guided into the sewer. As a rule of thumb, the length of the insertion trench should be 5 times the depth of the sewer. This can dramatically increase the cost of this technique when the existing sewer is quite deep. Alternatively, techniques developed for impact moling, where pipe sections are butt fusion welded in the trench rather than at the surface, could substantially reduce the cost of conventional sliplining in deep sewers. Use of the push method for insertion normally includes placing the pipe sections individually rather than welding on the surface.

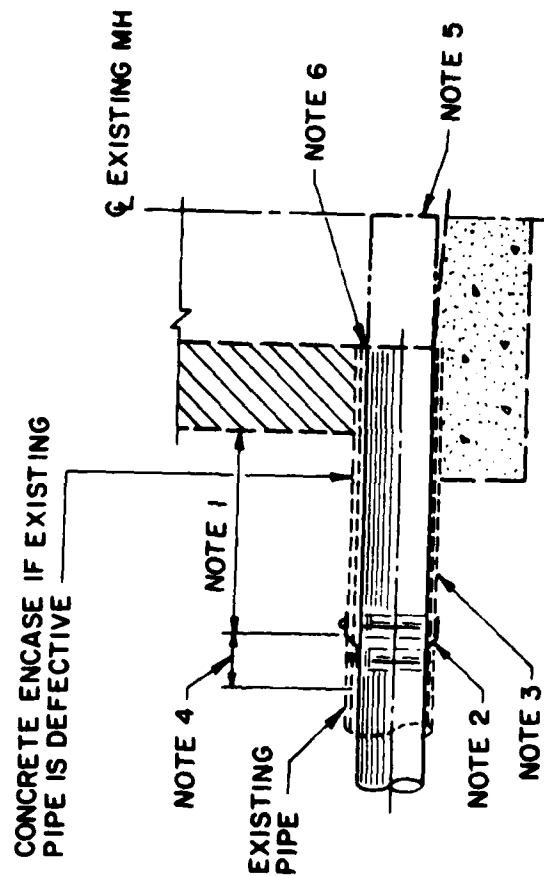
The advantages of this process are that an existing, partially failed sewer is replaced with a new pipe, minimal excavation is required compared to open trench work, and it is more cost effective than open trench work. The disadvantages are that cross-sectional area is lost and excavation is not completely eliminated.

Two improvements to the sliplining technique are currently under development. Both are intended for systems in which obstructions and displacement in an existing sewer would result in more than a 10 percent loss of the cross-sectional area using conventional sliplining. Two new materials are involved: shrink-fit high density polyethylene (HDPE) and thermally deformed HDPE. Shrink-fit HDPE is deformed using rollers¹¹ while thermally deformed HDPE is shrunk using heat. The pipe is then pressurized to recover its original size, without losing the structural properties of the HDPE pipe. This allows the pipe to negotiate some tight spots, while still providing the maximum cross-sectional area possible in most of the pipe.

¹¹"Shrink-Fit HDPE Liners for Water Mains and Sewers," *Water Quality International* (1987), No. 2, p 46.

NOTES

1. SAW CUT EXISTING PIPE, LEAVING 18" STUB.
2. ATTACH FLEXIBLE COUPLING TO STUB.
3. PUSH/PULL SLIPLINER THROUGH COUPLING.
4. REMOVE EXISTING PIPE AS NECESSARY TO SECURE COUPLING TO STUB AND LINER.
5. AFTER 16 HOUR PERIOD CUT LINER FLUSH WITH INTERIOR MANHOLE WALL.
6. IMMEDIATELY AFTER CUTTING LINER INSTALL WATERPROOF SEAL AND GROUT ANNULAR VOID BETWEEN LINER AND EXISTING PIPE FLUSH WITH INTERIOR MH WALL.



UPSTREAM AND DOWNSTREAM CONNECTIONS

H **2/11** **SLIPLINE CONNECTION AT MANHOLE DETAIL**
NOT TO SCALE

Figure 5. Detail of flexible coupling attachment between existing manhole and sliplined pipe. (Source: Ken Morin, Naval Facilities Engineering Command, Chesapeake Division.)

Insituform

Insituform is a patented inversion liner process in which a pliable felt tube is inverted on itself and forced into the sewer line by water pressure. The patent is held by Insituform of North America, Inc. The flexible felt liner is treated with thermo-setting polyester or epoxy resins prior to inversion into the sewer main. The existing system must be prepared in much the same way as for conventional sliplining in terms of cleaning; however, the pliable nature of the felt material allows the Insituform process to negotiate displaced pipes much better than the rigid polyethylene liner. Figure 6 shows the steps involved in the Insituform process.

First, an inversion tube is placed in a manhole with the resin-impregnated liner attached at the elbow. This is shown in Figure 6a, in which the darker lines represent the liner as attached to the inversion elbow. Water is then pumped into the inversion elbow, forcing the liner to invert against itself as it progresses into the existing sewer, as shown in Figure 6b. A water line is attached to the end of the resin impregnated liner to aid in later recirculation of water. Once the tube is fully extended to the destination manhole, the cold water used to force it into the pipe is heated and recirculated, as shown in Figure 6c. The hot water cures the resin impregnated liner into a solid lining.

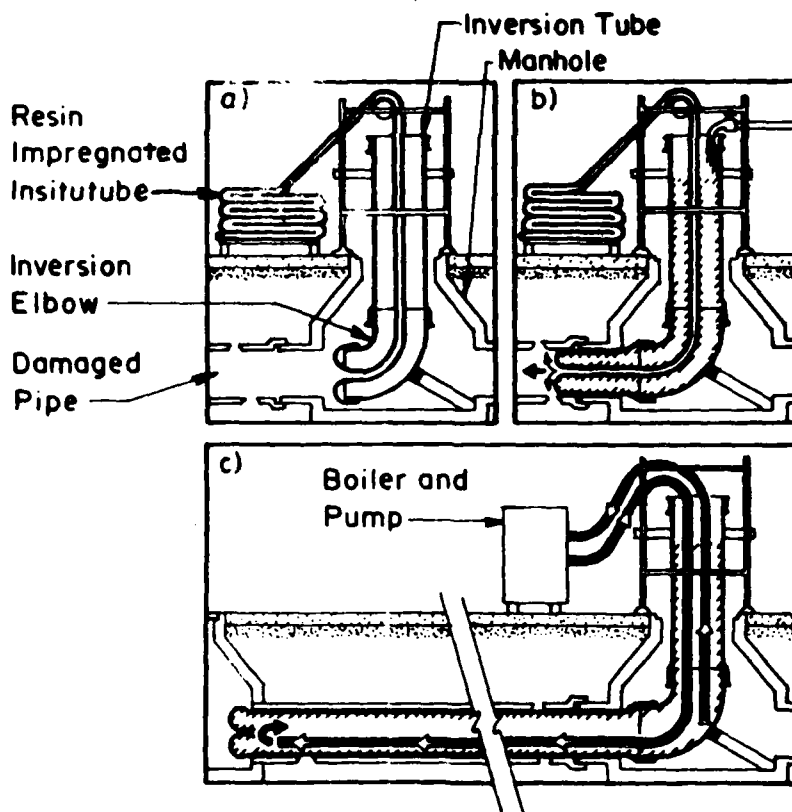


Figure 6. Insituform inversion tube rehabilitation process. (Source: Manufacturer's literature, Insituform of North America, Inc.)

Polyester resins are less expensive and may have better chemical resistance to acids, but phenols (which may be present in tar linings of the existing pipe) can interfere with curing of polyester. Also, polyester does not bond as well as epoxies to the existing pipe, so epoxies may be preferable. Any resin specification should include consideration of all industrial wastes which may come in contact with it, to ensure the compatibility of materials.

The excess cured liner is cut away at the manholes and any gaps are grouted in place. The service lateral connections are opened by a machine which cuts the liner from inside the main line pipe. This machine is a combination camera and cutter, allowing the operator to observe and control the cutting operation. Laterals which experience water backup due to residential discharge or infiltration cause problems for the cutting machine when the backed up water discharges, sometimes requiring the cutting machine to be withdrawn and cleaned up. In some cases the machine can not be sufficiently maneuvered to cut small boreholes, which means the laterals must be dug up and manually connected.

The advantages of Insituform are that most of the rehabilitation work can be completed without excavation and that complete service can be restored in under one day. Its main disadvantage is cost. If Insituform is specified in a contract, there is no cost competition because Insituform is a patented process. The only method to overcome this obstacle is to force Insituform to compete with other appropriate processes by specifying a rehabilitation goal and then specifying alternative solutions which could satisfy the requirements. Impact moling, discussed next, is a method which can compete under some circumstances. Open trench replacement, sewer realignment with existing mains converted to sliplined force mains, and conventional sliplining are other alternatives.

Army use of Insituform has been relatively limited due to cost. An article¹² describes applications on Department of Defense (DOD) installations. The results of USA-CERL's survey, shown in Table 4, indicated that only two Army installations had used the process.

Table 4
Use of Rehabilitation Techniques on Army Installations

Rehabilitation Technique	Instances of Use	Percent of Installations Responding
Grouting	9	37.5
Sliplining	11	45.8
Insituform	2	8.3
Open trench replacement	2	8.3

¹²A. P. Brigham, "A Pipe Within a Pipe," *The Military Engineer*, No. 517, September-October 1987, p 544.

Impact Moling (Pipe Insertion Machine)

Impact moling, or pipe bursting, is a new technique which was not considered in previous reviews of sewer rehabilitation¹³ because it was still under development. Originally proposed as an experimental approach for replacing gas mains by the U.S.S.R., researchers in the United Kingdom expanded upon the original concept and used it to replace gas, water, and sewage systems. It is currently marketed as the Pipe Insertion Machine (PIM) under a U.S. patent held by NUI Industries, Bridgewater, NJ.* Their efforts in the area of application have led to two categories of equipment and methods. The cast iron water and gas mains for which the PIM was originally developed were parts of pressure systems installed near the surface which included numerous valves for controlling flow. Sewage collection systems operated by gravity tended to be much deeper in the ground, and there were no provisions built into these systems for controlling flow. For these reasons, the sewage collection system pipe bursting techniques and materials differed somewhat from that for cast iron systems.

USA-CERL conducted the first demonstration of this technology in the United States. The technology and test are discussed further in Chapter 5.

Open Trench Replacement

Replacement of pipe using an open trench is similar to new construction. The major difference lies in reconnecting the new pipe to the existing pipe or manhole. EHSC's standard Statement of Work documents for inspection and rehabilitation of sewer lines (Appendix D) include specifications for constructing new sewers. The EHSC documents detail the elements of this technique in the work statements. Generally, the process involves excavating to open a trench, securing the trench as necessary to protect workers, removing the old pipe, placing and grading soil as necessary, installing and connecting the new main, backfilling, and restoring the surface.

One of the major costs in this process is surface restoration. Noncost items associated with diverting traffic and displacing local residents are impossible to quantify but should be included in consideration. The choice to be made between the various rehabilitation/replacement alternatives may be strongly influenced by surface restoration and social displacement costs. This is the area in which the apparently expensive alternatives (disregarding surface restoration and social costs) of Insituform and impact moling become more attractive.

Manhole Rehabilitation

Manholes can be a source of infiltration and/or surface water inflow. Surface water can enter through poorly sealed manhole covers, and through holes left in the manhole cover to allow its removal (pick holes). It can also enter under the frame if the frame is not sealed to the manhole structure itself. Manhole covers are also damaged by freeze-thaw cycles, heavy traffic, road work, and snow plows.

The manhole structure may be brick, or (in newer ones) precast concrete. Differential settling can cause cracks in the brick or between the units of a precast concrete.

¹³Thomas I. Simmons and Associates; *Utility Infrastructure Rehabilitation*.

*U.S. Method Application Patent Number 4738565.

The surfaces are also subject to attack by sulfuric acid as described previously for crown corrosion.

Manhole covers can be rehabilitated by placing bolts and caulk into pick holes to alleviate direct surface water entrance. This solution prevents gas transfer between the atmosphere and the sewer, creating undesirable differences in gas pressure between the atmosphere and the sewer. Flexible gaskets are usually installed with a manhole cover to produce a self-seal. If these gaskets are missing or damaged, they can be replaced with a duplicate, or by a commercially available manhole insert with gas relief valves as shown in Figure 7. This insert is designed so the lip rests directly on the manhole frame; the manhole cover rests on top of the lip. This allows gas transfer between the sewer and the atmosphere, but keeps out surface water. Use of either a new gasket or cover insert will not be effective if the manhole has been damaged and bent, since gaskets require a perfect fit. Use of cover inserts was estimated to have reduced the surface inflow in Atlanta, GA by 50 percent.¹⁴ The article cited appeared in the "Products at Work" section of the magazine and should not be viewed as a true case-control study, but the data presented did indicate substantial improvement.

Point repairs in the seal between the metal frame and brick can be made using cement, oakum rope and/or joint sealing tape. Cement repairs should be coated with a waterproofing epoxy to protect from sulfuric acid attack. For manholes which are subject to ponding during precipitation, raising the manhole using manhole adjusting rings or frame extending rings may be necessary. The exposed portion of the manhole should be protected using cement mortar or bituminous material. Data collected at Minneapolis-St. Paul, MN¹⁵ indicate that freeze-thaw cycles around the frame seal displace the frame; then pebbles get stuck and the frame rests on them after a complete thaw, causing substantial surface inflow. Thus, it is critically important to effect a very good seal, or the freeze-thaw cycle could rapidly enlarge any opening. In addition, the Twin Cities study indicated that cement coatings on raised manholes have severe problems with cracking and spalling. Their solution was to custom-make precast extensions at each manhole.

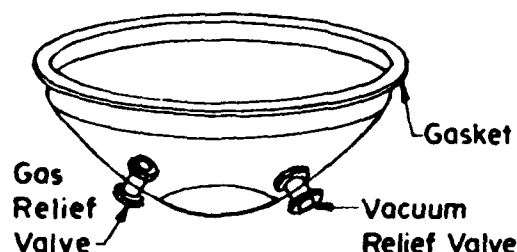


Figure 7. Manhole lid insert. (Source: *Existing Sewer Evaluation and Rehabilitation*, American Society of Civil Engineers Manuals and Reports on Engineering Practice No. 62/Water Pollution Control Federation Manual of Practice No. FD-6 [Lancaster Press, Lancaster, PA, 1983].)

¹⁴"Manhole Inserts Reduce Inflow 50 Percent," *Water Engineering and Management* (June 1984), Vol 131, No. 6, p 19.

¹⁵R. W. Arbour, "Manhole Rehab Produces Results in Twin Cities," *Water Engineering and Management* (January 1985), Vol 132, No. 1, p 30.

Rehabilitation of the manhole itself may or may not be possible depending on the level of deterioration. Sulfuric acid attack, as well as some industrial chemicals, can cause serious structural deterioration: concrete dissolves and exposes reinforcing steel in precast manholes, and cement mortar deteriorates in brick manholes. Metal manhole steps can also be seriously corroded, causing safety problems for workers. Manhole rehabilitation usually involves grouting from the inside or outside, which will not correct structural defects, or applying a cement coating, which can improve structural characteristics in some cases.

Chemical grouting is the most common method of side wall and base repair. Grout can be pressure-injected into existing cracks or into holes drilled in the vicinity of existing cracks. This method was used at Minneapolis-St. Paul.¹⁶ Based on that work, the payback period for grouting was estimated at 2 to 4 months.

Grouting with natural clays on the outside of the manhole can also provide a barrier to water movement. This method involves pumping a clay slurry into the ground immediately adjacent to the manhole. Clays swell when wet, dramatically decreasing their permeability to water. The clay thus provides an impermeable curtain surrounding the manhole.

Cement linings can also be applied, using the shotcrete or gunite method described under sewer lining. In the case of manholes, anchors would be placed throughout the manhole to transfer forces between the lining and the existing manhole, and then the cement lining would be applied. Structural problems where the reinforcing bars in concrete manholes have been exposed but not destroyed may be repaired by this process.

For extreme structural problems, a liner can be inserted in the existing manhole. This requires removing everything from the cone section up. A liner is installed, using grout to seal the base and annular space. The liner must be cut for all pipes entering the manhole, and the cone and frame must then be restored. This is an expensive, complex operation and may or may not be less expensive than replacing the whole manhole with a precast concrete one.

Lateral Rehabilitation

Correcting defects in the main line sewer will not eliminate infiltration if sewer laterals are also in poor repair. The main line sewer rehabilitation may merely shift the point of entry. The USEPA has sponsored several studies on the effectiveness of I/I reduction.¹⁷ One study found that a major problem encountered during rehabilitation in the public and private sectors is the distinction in ownership and responsibility for laterals. The laterals may come under sewer district control up to the property line and under building and plumbing code control between the property line and the building.¹⁸ This distinction sometimes leads to disputes over responsibility for repair. A homeowner considers a lateral operational as long as no blockage (e.g., root growth) makes sewage back

¹⁶R. W. Arbour.

¹⁷R. Sullivan, M. M. Cohn, T. J. Clark, W. Thompson, and J. Zaffle, *Sewer System Rehabilitation and New Construction*, EPA-600/2-77-017d, NTIS No. PB279248 (USEPA, December 1977); C. H. Steketee, *Demonstration of Service Lateral Testing and Rehabilitation Techniques*, EPA-600/2-85/131, NTIS No. PB86-135647 (USEPA, November 1985).

¹⁸R. Sullivan, et al.

up into the house; a leaky lateral is not a problem to the homeowner, but it causes problems for the sewer district. The Army is unique in that the installation is responsible for the sewer, the lateral, and the building. For this reason, Army contracts for sewer rehabilitation should consider lateral rehabilitation simultaneously, and not be patterned after private and public sector work.

The design of laterals, which includes a gentle slope followed by a bend and then a steep plunge into the main sewer, creates some difficulties and some advantages. The difficulty arises from the bend, which precludes sliplining even when a cleanout is available. The steep grade after the bend is an advantage if the groundwater table does not rise above it, because rehabilitation may only require work on the steep grade portion. There are several methods used to rehabilitate laterals, including:

- Pump-full-and-auger
- Sewer sausage
- Lateral Sealing System (patented)
- Test and grout
- Insituform (patented)
- Replacement.

Pump-full-and-auger is an older method in which a plug is placed in the lateral and chemical grout is forced up to the point of the plug under pressure using a camera/sealing packer unit. The camera is used to locate the lateral, and the back pressure provided by the plug forces grout through cracks and crevices and into the surrounding soil. An auger is then used to remove the excess grout and open the lateral for service.

The sewer sausage method uses an inflatable tube inserted at the lateral cleanout in a modification of the pump-full-and-auger method. It still requires a camera/sealing packer unit, but a long flexible tube is inserted through the cleanout to the main. Grout is pumped through the annular space between the inflated tube and the lateral, cutting down on the use of grout compared to the pump-full method.

The Lateral Sealing System is a patented process (CUES, Inc., Orlando, FL) which completes all work from the sewer main. The system uses a camera to locate laterals, then moves the sealing packer into place to allow an inversion tube to come out of a side port of the inversion packer. This tube then is inflated into the lateral. The original design was for 3 to 8 ft of tube, but the process is being modified for installing much longer inflatable tubes. The sealing packer is then used to pump grout into the annular space between the inflated tube and the existing pipe. This was initially designed to repair parts of the steep area of the lateral. The Lateral Sealing System was found to be effective in reducing I/I at Salem, OR.¹⁹

¹⁹C. H. Steketee.

Test and grout has been used to a small extent by inserting a system into the clean-out and grouting for predetermined lengths (4 to 8 ft). This is similar to camera/sealing packer methods, except that the entire pipe is treated rather than areas which show cracks and joint breaks.

Insituform is in the process of developing the mechanical methods capable of delivering resin-impregnated liner to smaller laterals. Beyond the mechanics of delivering the system, the curing and sealing would be the same.

Replacement is the most common method of lateral rehabilitation. This is required when the line is collapsed or seriously deteriorated, and may be an economical alternative on Army installations when other processes which require lateral excavation for reconnection already are being used, such as sliplining or the PIM technique.

A final consideration in lateral rehabilitation is the problem of infiltration from abandoned laterals. This is more of a problem for older cities than new ones, but it may be an even greater problem on Army installations, due to the use of temporary buildings and to the rapid construction required in the 1940s. Lateral connections may lead to former building sites, at which the lateral may have been properly sealed off. However, this does not address infiltration along the old lateral.

Camera studies during dry weather can identify "live" laterals by inducing high flows in all buildings which may drain to the sewer under study. Induced flows are generated by flushing toilets, letting spigots run, etc. Laterals which do not flow under these conditions should be plugged. There are commercially available systems to insert plugs from within the main sewer.

However, plugging laterals can lead to problems in areas which used illegal connections such as sump pumps (which would not be operating during dry weather), roof leaders, and floor drains. These should in general not be connected to the sanitary system, except possibly for floor drains which are used to drain cleanup wastewater from industrial areas. Such drains in industrial areas should be identified by inducing flow in them and looking for them during the camera study of the system.

Miscellaneous Rehabilitation Techniques

The discussion above dealt with methods designed to rehabilitate specific units of a wastewater collection system such as the main line sewer, the manholes, and the laterals. This section will deal with three patented systems which could be used at various locations or stages in the process of rehabilitating a collection system:

- Lateral Inspection System (patented)
- Rerounder (patented)
- Weko-Seal (patented).

The Lateral Inspection System (LIS) was developed by CUES, Inc. of Orlando, FL to inspect building laterals from within the sewer main. This was actually a forerunner to the lateral rehabilitation technique which uses an inflatable tube from within the main.

A camera unit identifies the location of laterals throughout the collection system and pulls behind it a second, smaller camera unit housed in a cylinder with a side port. The side port is positioned adjacent to the lateral, and the small camera is extended into the lateral. The small camera can negotiate 90 degree bends; thus it can usually pass any bend in the lateral. The current technology allows the camera to inspect up to 30 ft of lateral.

The Rerounder, patented by Williams Testing, Harrod, OH, is a device which can be used to restore the proper cross section to a flexible pipe. Flexible pipe deforms under external loads. This property can lead to partial collapse and loss of carrying capacity. The Rerounder uses a pneumatic vibrator to force the flexible pipe back into place while compacting the soil outside the pipe. This will not correct all problems which lead to partial collapse, such as surface loads and poor bedding, but it can restore proper flow characteristics until the forces cause a recollapse.

Weko-Seal is a patented process (Miller Pipeline Corp.) to rehabilitate leaking joints. It is available for intermediate to large diameters (12 to 138 in.) and can span gaps of 4.5 in. in its standard sizes. Other sizes are available for gap repairs up to 9 in. Good results have been shown on up to 8 in. gaps²⁰ and it has been used on hundreds of thousands of individual joints.²¹ This process may be usable wherever leaking joints are a problem, and can be used in conjunction with grouting, using Weko-Seal for the largest gaps. It does not offer structural repair for the adjacent pipe.

²⁰B. R. Elmore, "Sealing Leaks That are Hard to Reach," *Public Works* (March 1984), Vol 115, No. 3, p 64.

²¹Utility Infrastructure Rehabilitation.

5 INVESTIGATION OF IMPACT MOLING TECHNOLOGY

The Water Research Centre of the United Kingdom, in cooperation with two consulting engineers (Alan Lippincott Hobbs, Ltd. and D. J. Ryan) and a regional water authority (Southern Water Authority) worked together to investigate the usefulness of the Pipe Insertion Machine (PIM) for sewage collection systems. Four areas critical to operational suitability of the method were accurate lateral location, effective connection of laterals, material suitability, and pipe bursting.²²

Material suitability considerations required that pipe to be inserted meet the following criteria:

- Structural adequacy
- Flush joints both inside and out
- Quick and simple jointing
- Able to withstand end jacking loads
- Joints not adversely affected by jacking
- Resistant to surface abrasion
- Capability to meet normal testing criteria (pressure and flow).

Modified HDPE pipes with "snaplock" joints and polypropylene pipes with screwed joints and a rubber O-ring seal were found to satisfy these criteria.²³ The basic material, HDPE, is the same as that used for conventional sliplining rehabilitation. This material has been used extensively in the United Kingdom for gas main replacement. Although less is known about sewer line replacement with this technique, several case histories presented later in this chapter illustrate the potential usefulness of this process and represent lessons learned in changing the method from water and gas main replacement to sewer collection system replacement.

Impact Moling Procedure

This process for inserting new main is similar to sliplining, except that the space for the new main is created by bursting the pipe in place and forcing it into the surrounding soil. The existing pipe provides the path which the impact mole follows, maintaining the same manhole to manhole route. The new HDPE pipe sits in a shroud attached to the mole, and the mole is pulled through the existing pipe to the next manhole, while the new pipe is pushed into the hole created by the mole. The shroud allows the new pipe a limited amount of independent movement; thus pipe and mole need not be exactly synchronized. Figure 8 shows a conceptual diagram from the manufacturer's literature, although the hydraulic pushing machine is not shown in this drawing.

²²A. P. Poole, R. B. Rosbrook, and J. H. Reynolds, "Replacement of Small Diameter Pipes by Pipe Bursting," in proceedings of the No-Dig 1985 Conference, "Trenchless Construction for Utilities," London, U.K., April 1985.

²³A. P. Poole, et al.

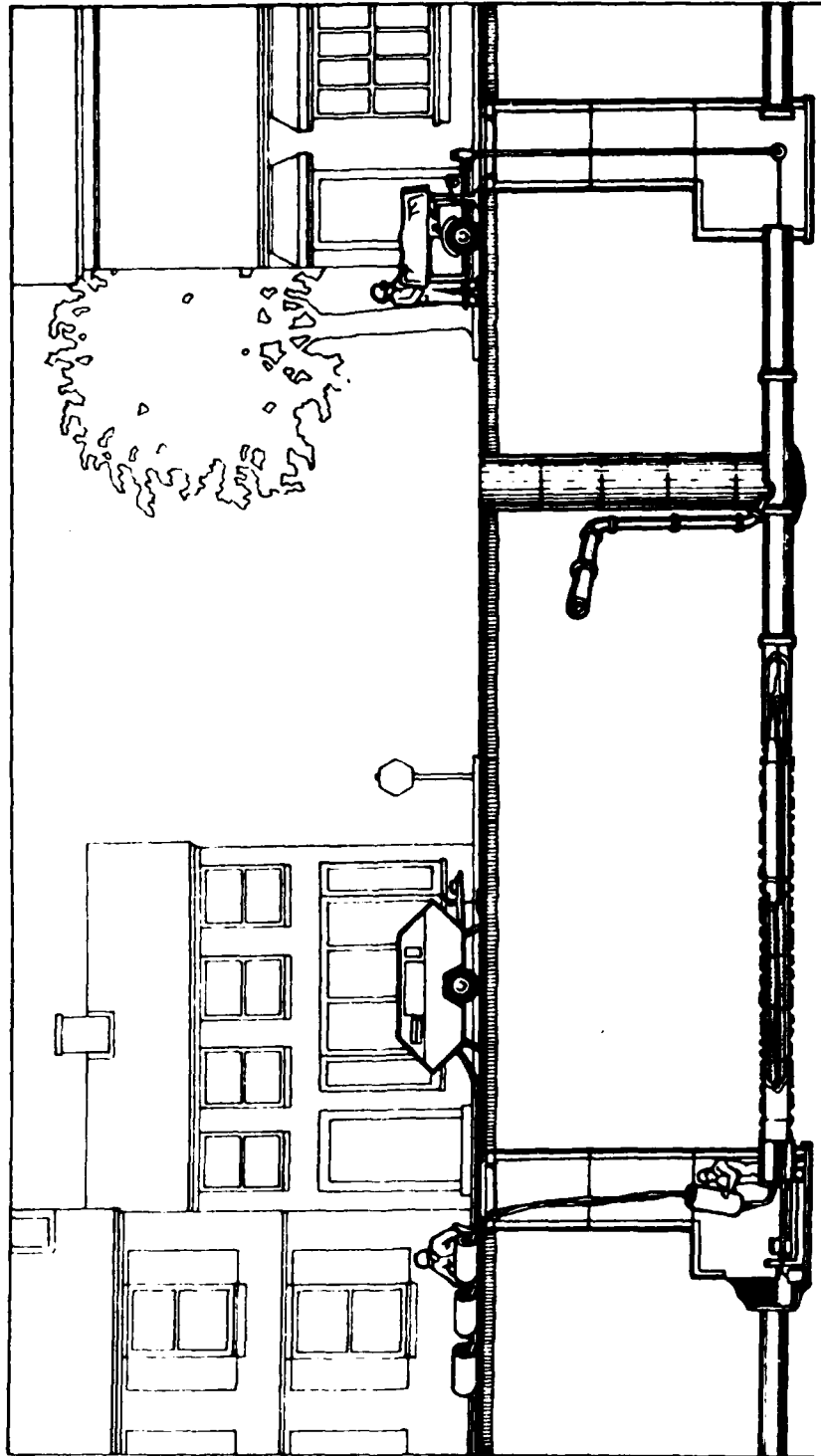


Figure 8. Pipe insertion machine process for replacing sewer pipe. (Source: Manufacturer's literature, PIM, Division, NUI Industries, Bridgewater, NJ.)

Laterals are identified and catalogued using TV inspection of the existing pipe prior to insertion; this list is compared to the record for existing building patterns. In older systems, abandoned laterals can significantly contribute to infiltration. Service laterals are individually dug up and reconnected to the system.

In cases of shallow replacement, an insertion trench may be constructed identical to the type used for conventional sliplining. In deeper pipes, short pipes are continually added to the new main. Although this requires disconnecting the mole unit air hose for each section, the savings from avoiding a large trench may more than offset the effort required. In addition, methods for prestringing several pipe sections can reduce the downtime.²⁴

Case Histories

Edgar Road, Winchester, U.K.

The replacement of a 229 mm (9 in.)* clay sewer required renovation of 800 m (2600 ft), using conventional sliplining for 230 m (750 ft) and "size for size" replacement in the remaining 570 m (1850 ft). Service laterals were disconnected prior to using the impact mole. In addition, the Water Research Centre installed a monitoring pipe 20 m (65 ft) from the insertion pit and 1.5 m (5 ft) from the sewer being replaced, to monitor increase in strain as the mole passed. The effects of the impact mole were considered insignificant at this distance.²⁵

This work was completed during November 1983, and was one of the first full scale demonstrations of this technology. As such, several innovations were developed and multiple types of replacement pipe were used. For this project pipe was assembled in the pit (rather than in a long insertion trench); this kept the rate of replacement on the order of 10 to 20 m (33 to 65 ft) per hour. Conversely, it demonstrated the effectiveness of using a small pit in congested areas.

An alternative to hand excavation was employed in working on service laterals. A pit was opened to a depth of 1 m (3 ft) to insure that no other utilities were in the street, and then a truck-mounted auger was used to form a 900 mm (3 ft) diameter shaft to work on the service lateral. These shafts were lined with steel shields to protect the workers, and were found to substantially increase the rate of work on service laterals.

The cost of the contract for this case study was essentially equal to the open cut alternative. The nonmonetary benefits were considered significant because a narrow road would have been closed to traffic for the replacement period if open trench methods had been used. The Southern Water Authority of the United Kingdom was sufficiently impressed to offer a second contract, described in the next case study.

²⁴A. P. Poole, et al.

*The metric-to-English conversions provided for convenience in these case histories are only approximate. Exact conversions can be made using the factors given at the end of this report.

²⁵C. Darling, *Pipe Strain and Vibrations Caused by Percussive Molding: Site Experiment No. 2*, External Report No. 154E (Water Research Centre).

Tonbridge, U.K.

In this case,²⁶ a badly corroded 230 mm (9 in.) cast iron sewer running to a pumping station was situated in very difficult conditions. The pipeline ran a distance of 3 m (10 ft) between two houses at a depth of 4.5 m (15 ft) in water-bearing gravel. This lay within the zone of influence of one of the buildings' foundations, and conventional open cut work would have required pre-grouting the gravels prior to excavation. An insertion trench was dug at a 45 degree bend in the sewer line. The impact mole placed new pipe from the bend to each of two existing manholes, and then a new manhole was installed at the insertion trench. Sewage flow had to be pumped around the line being replaced during the construction.

The total length of sewer replaced was 100 m (330 ft). In this case, a 250 mm (10 in.) HDPE pipe was put into the line previously occupied by a 230 mm (9 in.) line. A 10 bar (145 psi) pipe was chosen over a 6 bar (87 psi) pipe for added protection against the potential abrasion from metal fragments left by the impact mole. Pipe was supplied in standard 12 m (40 ft) sections and butt-fusion welded into a continuous length at the surface, which required an insertion trench. The new pipes were inserted in May 1984. The rate of insertion started at 40 m (130 ft) per hour but rapidly slowed to 15 m (50 ft) per hour as the soil settled back against the HDPE pipe as it was pulled in, impeding its progress. No cost data were presented in this case study.

St. Cross Road, Winchester, U.K.

St. Cross Road is the major thoroughfare into the center of town at Winchester. Traffic reaches 1600 vehicles per hour, but the road is only 5 m (16 ft) wide at some stretches. Discussions with contractors indicated that the road would have to be closed for approximately 30 weeks to use conventional methods for replacement. The dilapidated sewer was a 9 in. clay pipe over 100 years old, laid at a depth of 3.5 m (11.5 ft) under the center of the road.

A combination of methods were used to replace this sewer, representing a cost comparison of engineering alternatives.²⁷ Conventional sliplining was used for a 200 m (650 ft) section, and impact moling with size for size replacement was used for 822 m (2750 ft). Rerouting of a portion of the sewer was also required, thus open-cut work accounted for 65 m (200 ft) of the renovation. The contract also called for construction of six manholes. Using the impact moling technique, the entire contract duration was estimated at 12 weeks.

A road closure order was issued due to the location of the sewer and the large potential for heavy vehicle traffic. However, access was maintained at all times for residents and commercial activities. Six sections of the pipe were placed using the impact mole technology. The lengths of the replacements ranged from 50 to 130 m (160 to 425 ft). The actual work schedule took nine weeks, and the road was opened to all traffic at the end of that time. This was less than one third of the time projected for open trench rehabilitation.

These first three projects were essentially experiments which occurred under the supervision of the Water Research Centre. The following examples are cases in which the use of impact moling was selected based on cost-effectiveness. The construction

²⁶A. P. Poole, et al.

²⁷A. P. Poole, et al.

dates are not specified, but both articles appeared in the July 1986 issue of *Underground*, a monthly trade magazine in the United Kingdom.

Harlow, Essex, U.K.

In this project, three separate runs of sewer were installed using the impact moling technique. The first section was 143 m (470 ft) of 152 mm (6 in.) clay sewer which was replaced by 180 mm (7 in.) HDPE pipe under gardens which were undisturbed during the process. The next section was 62 m (200 ft) of 225 mm (9 in.) clay sewer which was replaced by 255 mm (10 in.) HDPE pipe under a major roadway. The third location is not well defined except for a problem which occurred. A large block of concrete was encountered under an unoccupied stretch of the shoulder of a road. At that point, the impact mole had to be dug up with a backhoe, and the operation was down for three hours.

This article²⁸ includes the first mention of some of the engineering limitations attributed to the soil. The experimental work at Tonbridge had shown remarkably different characteristics compared to the two tests at Winchester. The difference was attributed to the speed with which the soil settled in around the pipe after insertion. The initial work was accomplished with a 10 mm (0.4 in.) difference between the size of tunnel cut by the impact mole and the outside diameter of the HDPE pipe. In the soft clays of Winchester, the soil recovered more slowly (on the order of two days) and the friction between the pipe being pulled and the soil did not increase dramatically during installation. At Tonbridge, the saturated gravel recovered within hours, severely reducing the speed at which the HDPE pipe could be pulled. To increase the speed, a larger gap of 25 mm (1 in.) was used.

A major difference between the technology used for sewers and that used for shallow gas or water main replacement is the use of a jacking machine at the insertion trench as well as the pull from the forward direction. In fact, the HDPE pipe is both pushed and pulled into place. Another innovation required for sewer work is a PVC shield following behind the impact mole. This is designed to take the initial abrasion in the newly formed cavity and to help protect the HDPE pipe which trails behind. The article reports that the largest pipe installed by this technique so far is 89 m (290 ft) of 355 mm (14 in.) new HDPE pipe which was inserted into a cavity originally occupied by a 305 mm (12 in.) sewer. It was estimated that with the current design, it would be possible to install up to 400 mm (16 in.) pipe over a distance of 160 m (525 ft).

Heathrow Airport, U.K

British Airways was having problems supplying water to an export building which was isolated from open space by an apron of the runway and a truck maneuvering area. Bursts in the main disrupted supply four or five times a year. The entire project was accomplished using the impact mole, including 202 m (660 ft) of 90 mm (3.5 in.) HDPE water line.

Costs for impact moling under the airport runway apron exceeded those in communities due to the cost of inserting a pit in the concrete. Up to 2 m (6.5 ft) of concrete were encountered in constructing the insertion pit. However, the overall cost of the installation was one third of the estimates of the cost for open trench replacement. In addition, traffic was not severely affected.

²⁸M. Winney, "Sewer Mole Cracks Into Steady Routine," *Underground*, July 1986, p 18.

This example is not representative of sewer work, because the depth of the trench is not as great. However, it is representative of a scenario which may occur on an Army installation in which movement of heavy vehicles and aircraft may be involved. It also demonstrated the potential for cost savings in very specialized circumstances.

Test at Fort Belvoir, VA

USA-CERL, under the Facilities Technology Application Test (FTAT) program, conducted a test of this method at Fort Belvoir. Fort Belvoir was selected by discussions with MACOMs and visits to prospective sites. The candidate pipe replacement project had to meet the following restrictions:

- Existing pipe required upsizing
- Existing pipe material was not ductile
- Pipe route crossed several areas requiring substantial surface restoration.

Figure 9 is a copy of the plan view for the sewer rehabilitation in the area of 16th Street and Pratt Road on Fort Belvoir. The line to be replaced by the PIM technique ran from manhole (MH) 11-44 to MH 7-44. On the plan, it is shown running in close proximity to Building T-1108, under a retaining wall, a cyclone fence, and 16th Street. Although it is not clear on the drawing, the area over the pipe from 4 ft south of the cyclone fence and building T-1108, up to and including MH 7-44, is paved. The areas other than the street are parking lots. In addition, this area receives a steady stream of heavy vehicle traffic because the Directorate of Engineering and Housing (DEH) uses these buildings for vehicle and parts storage.

Figure 10 is a profile view of the section to be replaced. The existing pipe was a 6-in. terra cotta pipe and was to be replaced with an 8-in. pipe. The paved parking lots are shown on the elevation drawing (Figure 10), as well as a 10-in. water line. Based on the drawings and a visit to the site, Fort Belvoir was selected for the PIM technology demonstration, as it met the conditions listed above.

A series of experiments were also conducted in concert with the PIM technology demonstration. A ductile iron pipe was instrumented with strain gauges and installed 16 in. above and at a 90 degree angle to the existing sewer. Figure 11 shows the instrumented pipe in the trench. An additional, uninstrumented section of pipe was connected at both ends to add pipe continuity and make the test more realistic. Three displacement rods were placed along the line of the existing sewer and at various depths as shown in Figure 12. Geophones were placed on the surface to measure vibration caused by the mole's passing. These tests were devised to emulate pilot scale tests conducted at the Water Research Centre's Swindon facility. In addition, a device was constructed to measure pipe deformation after installation. The device contained two pistons at 90 degrees, and displacement transducers to measure piston movement as the device was pulled through the newly installed HDPE pipe.

Figure 13 shows the butt fusion welding apparatus used to join the individual sections of HDPE pipe into one continuous, 280-ft pipe. Figure 14 is a closeup of the expansion joint and shroud used to connect the pipe to the mole. This allows the mole and pipe to move independently. Figure 15 shows the mole just before it was attached to the pipe. The air hose to drive the pneumatic hammer is shown coming through the pipe. Figure 16 shows the insertion pit with the mole just entering the pipe.

The results of this test will be briefly presented here. Further technical details and interpretations will appear in future professional publications.

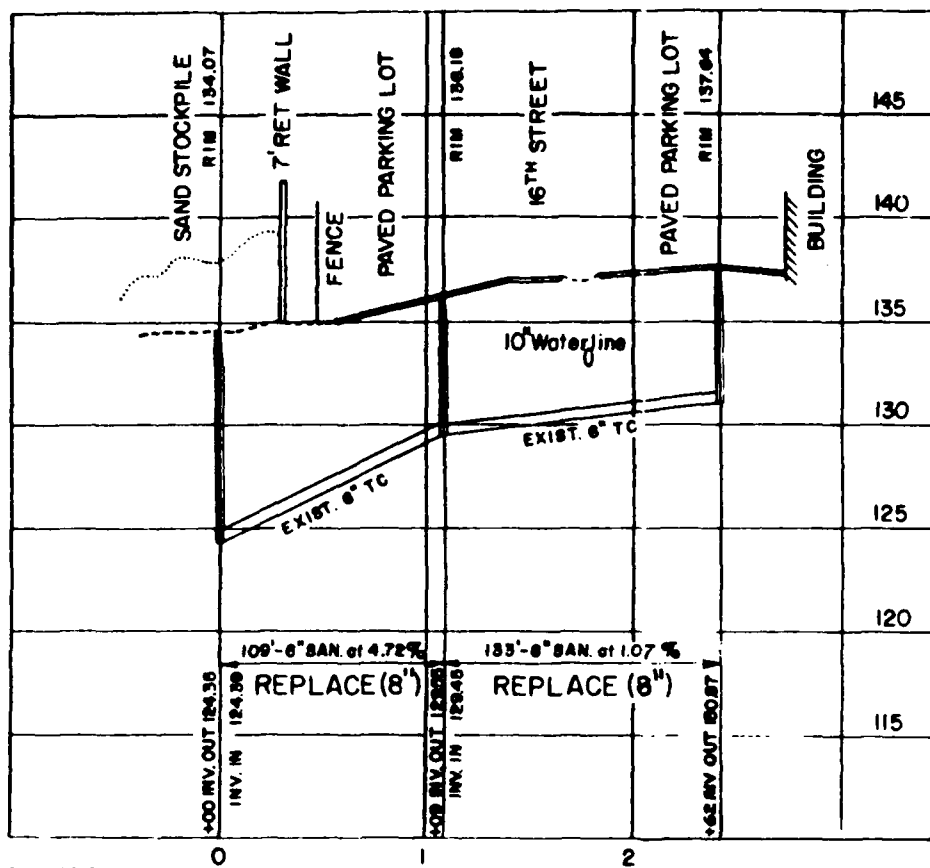


Figure 10. Profile view of pipe replaced using PIM technology and overlying surface paved areas and retaining wall.



Figure 11. Instrumented pipe placed in trench perpendicular to the existing pipe. Shiny areas are strain gauge locations.

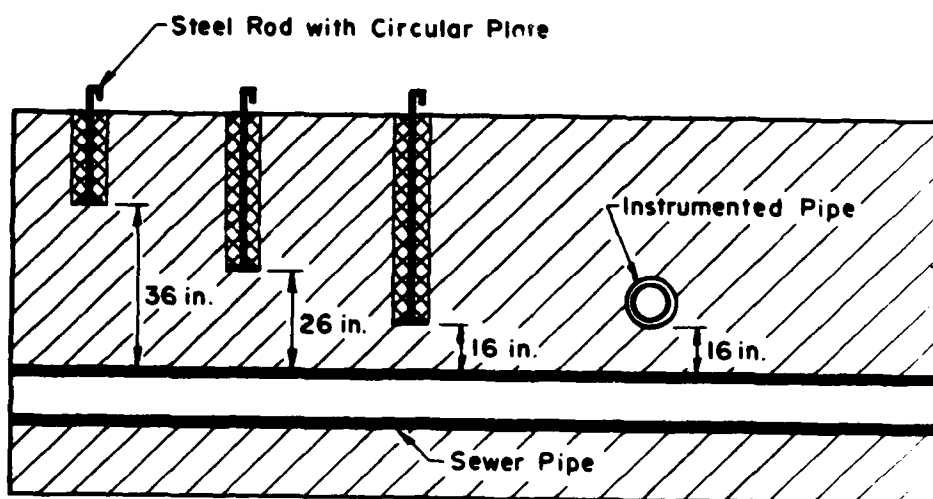


Figure 12. Schematic showing location of instrument pipe with displacement rods in relation to the existing sewer pipe.



Figure 13. Butt fusion welding process joining HDPE pipe.



Figure 14. Sliding joint connection for attaching HDPE pipe to impact mole.



Figure 15. Impact mole just before connection to HDPE pipe, showing air line inside HDPE pipe.



Figure 16. Impact mole/HDPE pipe after initial insertion in existing pipe.

Mole Speed

Figure 17 presents the advance of mole with time. In general, the mole shows a tendency to gain speed as it advances. This was unexpected since, in general, it was thought that friction would build up as the new pipe was inserted. This friction should gradually have lowered the mole's speed. However, friction on the new pipe during insertion depends very much on the soil type and predominately on whether it deforms plastically or "elastically." This behavior is discussed later.

The average speed of the mole was found to be 2.7 ft/min. The minimum speed was 1.4 ft/min and the maximum speed 4.4 ft/min. At the intermediate manhole, the mole hammer was stopped and the mole was manually guided through. The invert and pipe entrances had been previously broken out using a jackhammer to allow the mole to pass. The hammer in the mole was stopped to prevent further, unnecessary damage to the mole or manhole. Some difficulty was encountered in restarting the hammer, which is reflected in the flat portion of the graph.

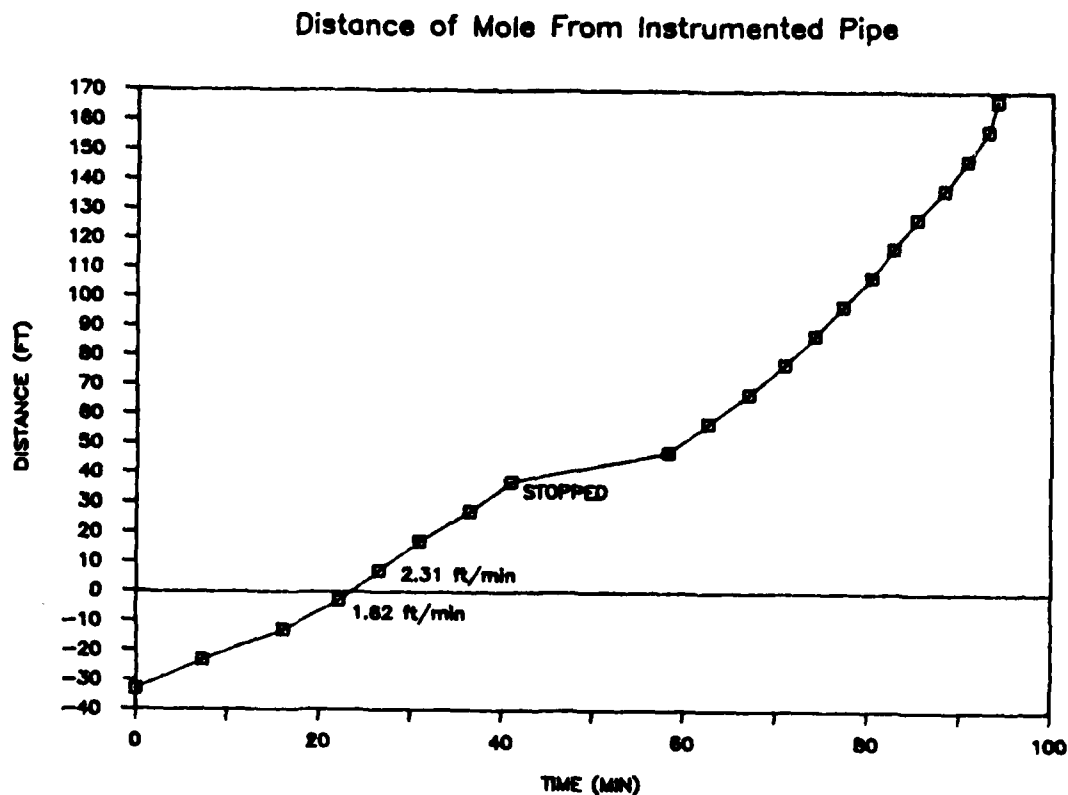


Figure 17. Mole's advance with time. The mole stopped while in the intermediate manhole; the numbers on the curve indicate average speed in the vicinity of the instrumented pipe.

Strain

The longitudinal strains introduced in the instrumented pipe were not found to be, significant, in general. As expected, maximum strain was developed at the crown of the instrumented pipe, just above the sewer pipe. This maximum was 200 microstrain units.

The distribution of strain along the crown line is shown in Figure 18. This is a classic strain (stress) distribution for a beam on elastic foundation. This distribution qualitatively duplicates corresponding strain distributions obtained from similar tests in the United Kingdom.²⁹ This is very encouraging because the United Kingdom tests were conducted by constructing a series of both instrumented pipes and pipes to be destroyed in the test; thus, there was no true existing pipe and long-term, stabilized backfill. At Fort Belvoir, the pipe was installed leaving 12 in. of undisturbed soil over the existing pipe, which more closely resembles the actual conditions which would be experienced by adjacent utilities. The similarity in results obtained indicates that the results obtained at the Water Research Centre are indicative of field conditions, and may actually be conservatively high, depending on the soil characteristics.

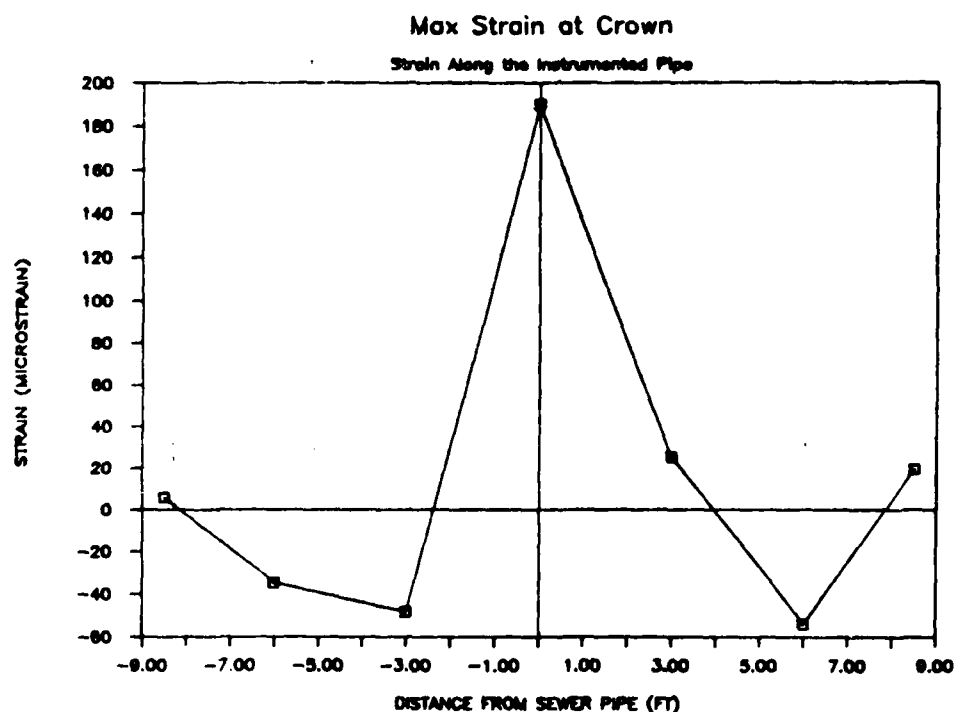


Figure 18. Longitudinal strain distribution along the crown line of the instrumented pipe when mole was passing (mole beneath instrumented pipe). Distance scale indicates distance of strain gauge from center line of instrumented pipe.

²⁹K. Reed, "On Line Replacement and Microtunneling Techniques," Proceedings of the Pipeline Management 87 Conference, sponsored by Pipeline Industries Guild, Institution of Water Engineers and Scientists, Institution of Gas Engineers, and Institute of Petroleum; held at Confederation of British Industries Conference Center, Center Point, London, 12-13 February 1987.

The variation of maximum strain at the crown over time, as the mole passed by the instrumented pipe, is shown in Figure 19. This strain distribution indicates that strain developed abruptly in the instrumented pipe when the mole approached at only 1.5 ft from it. After the pipe had passed by, a residual strain of 30 microstrain units still remained in the pipe. Again, these results are very much the same, qualitatively, as those obtained in the tests performed in the United Kingdom.³⁰

Strain developed along the springer line of the instrumented pipe, as the mole was approaching it, shows a distribution similar to the one of the crown line (Figure 20). The maximum strain of 80 microstrain units is rather low. The distribution of maximum strain over time (Figure 21), presents a clear picture of the relative lateral displacements experienced by the instrumented pipe as the mole was passing by. Maximum strain, associated with maximum lateral displacement, occurred when the mole approached at about 3 ft from the pipe. Then, as the mole was passing by the pipe, the pipe was pushed back by the displaced soil. This is inferred by the reverse of strains shown in Figure 20. After the pipe had passed, a very small residual strain remained along the springer line of the pipe.

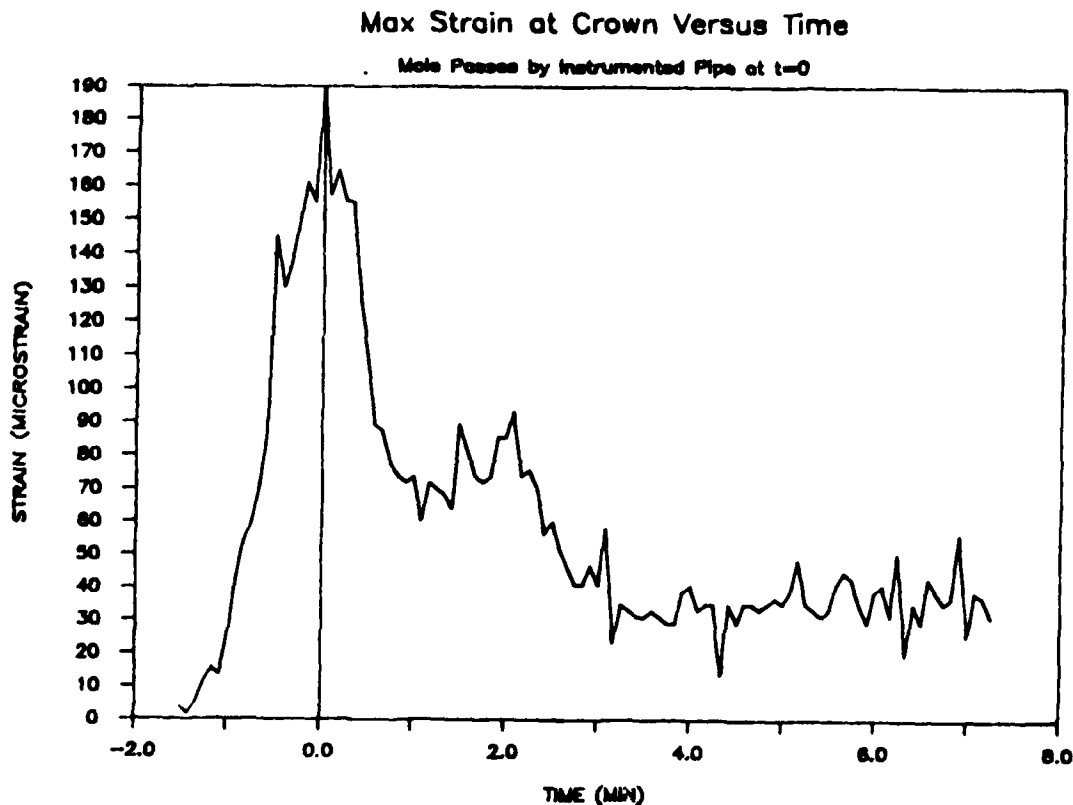


Figure 19. Variation with time in maximum strain at crown above sewer pipe.

³⁰K. Reed, "The Application of Molding Techniques in the Water Industry," No-Dig 87, Proceedings of the Second International Conference, sponsored by the International Society for Trenchless Technology, Kensington Exhibition Center, London, 14-16 April 1987, pp 2.2.1-2.2.10.

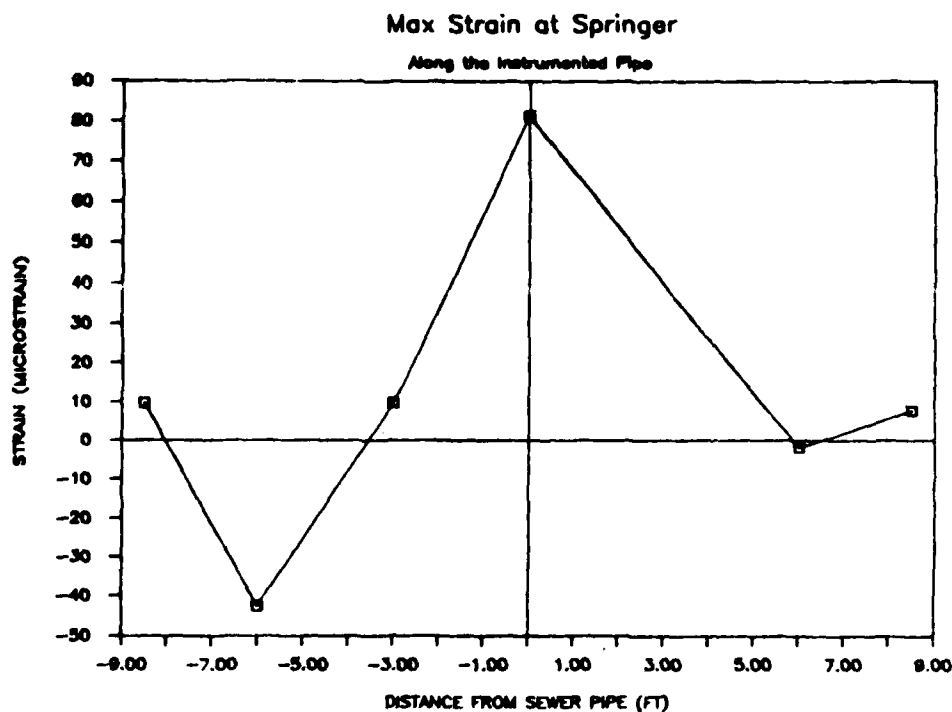


Figure 20. Longitudinal strain distribution along the springer line of the instrumented pipe when mole was approaching (mole approximately 3 ft. away from instrumented pipe). Distance scale indicates distance of strain gauge from centerline of instrumented pipe.

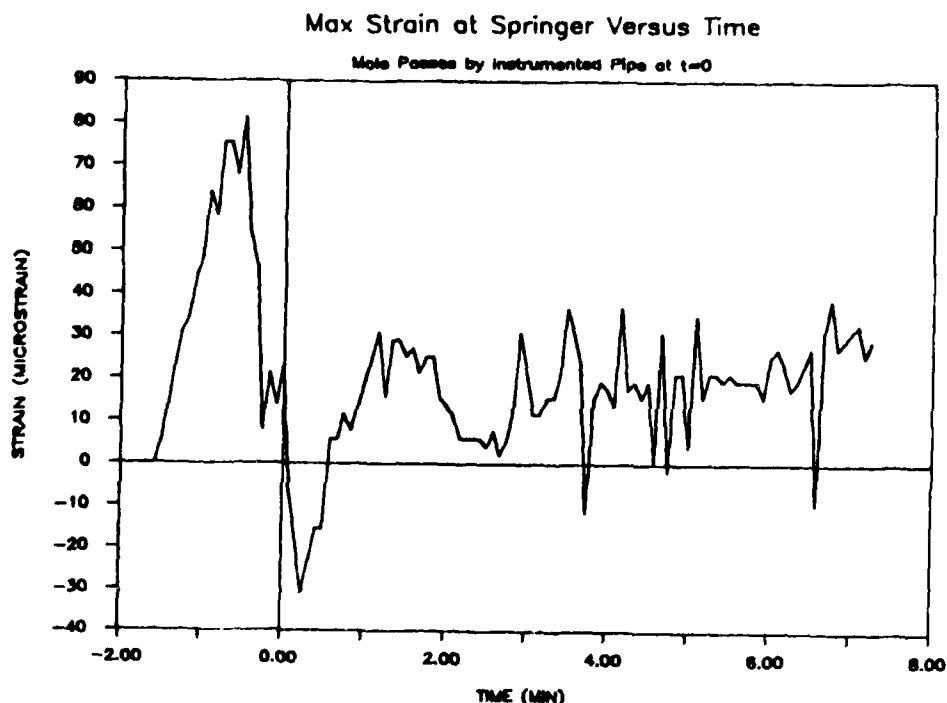


Figure 21. Variation with time in maximum strain at springer above sewer pipe.

The oscillations observed in the curves of Figures 19 and 21 are probably due to the dynamic effects of the mole operation. Taking measurements every 5 seconds was adequate to trace such effects. Note that noise (drift) due to the instrumentation cannot be excluded as a factor contributing to these small oscillations. Similar dynamic effects were observed in the United Kingdom tests through continuous recording of strain. Nevertheless, the amplitude of these dynamic effects (Figure 19) is rather insignificant, analogous to that recorded in the United Kingdom.³¹

Soil Displacement

The soil displacements measured at different elevations above the sewer pipe are shown in Figure 22. The maximum displacement was 0.60 in., measured at 16 in. above sewer pipe. This compares to an increase of pipe radius by 1 in., associated with an even larger expansion of the surrounding soil by the mole expanding action.

The general tendency observed in Figure 22 is that the soil experienced substantially plastic deformation in this test. This differs from the corresponding results obtained in the United Kingdom and may explain why the overall strains, displacements and vibrations are lower in this case. In addition, plastic soil deformation should be the reason why friction did not develop along the inserted new pipe, as noted above.

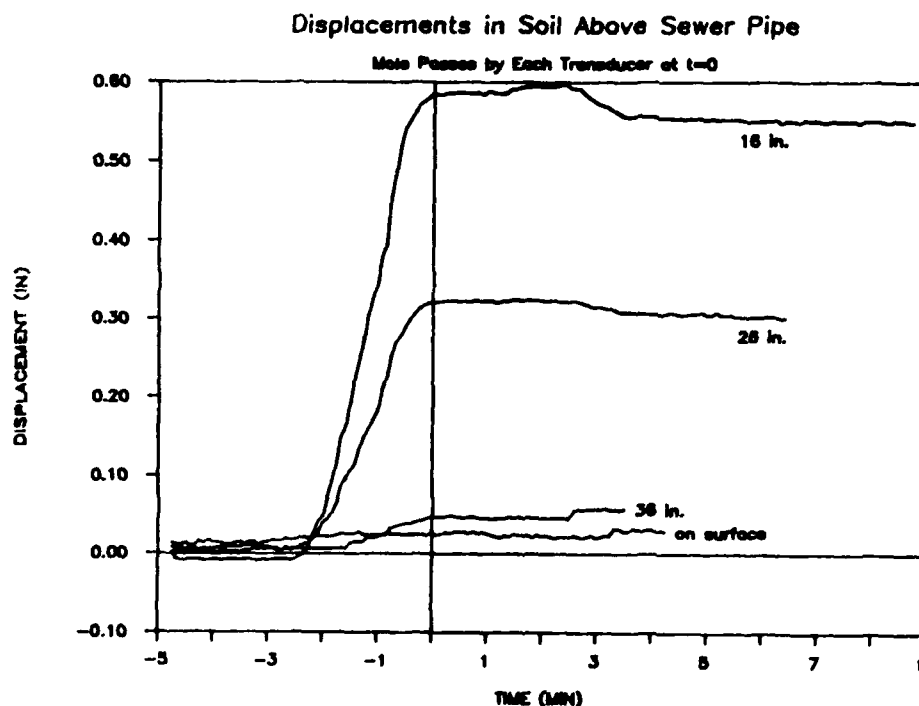


Figure 22. Soil displacement at different depths above sewer pipe as mole was passing. Results are normalized so that time zero corresponds to the time when mole was beneath each displacement transducer.

³¹K. Reed, "On Line Replacement and Microtunneling Techniques"; K. Reed, "The Application of Moleing Techniques in the Water Industry."

Vibrations

Vibrations monitored on the pavement above the sewer pipe were shown to be significant. Maximum vertical peak particle velocity directly above the sewer line was found to be 0.54 in./sec (135 mm/sec). This particle velocity may exceed allowable limits depending on building type. Vertical peak particle velocity did, however, dampen out quickly at locations other than directly above the sewer pipe. At a distance of 9 ft (2.74 m), the maximum vertical peak particle velocity was 0.08 in./sec (2 mm/sec). This suggests that proximity to certain types of building should be a concern in the use of the PIM method. Further tests on various soil types and distances will be required to establish a relationship between sewer depth, distance to building, soil type, and impact mole characteristics (e.g., diameter, hammer size, force on hammer) such that structures will not be affected by the PIM method.

Deformation of New Pipe

The deformation of the new polyethylene pipe, after it was inserted, is shown in Figure 23. Pipe deformation is described in terms of relative changes of the horizontal and vertical diameters. As the device entered the free end of the pipe, in the reception pit, it showed no deformation until it entered the buried pipe. A gradual increase of deformation of the pipe is shown in that region (Figure 22). The deformation pattern is elliptical, as expected, remaining almost constant as the device was pulled through the buried new pipe. The maximum deformation is shown to be equal to 2.5 percent of the pipe diameter. At the region of the butt fusion weld joint, however, located approximately 38 ft from the free end, the device was stuck (and pulled back). An inner circumferential rib, left by the butt fusion procedure used to form the joints, did not allow the device to go through the rest of the pipe.

The new pipe will be monitored for deformation over a period of 1 year, to investigate the time dependence of pipe deformation under the soil conditions of this test. The results will be presented in future articles.

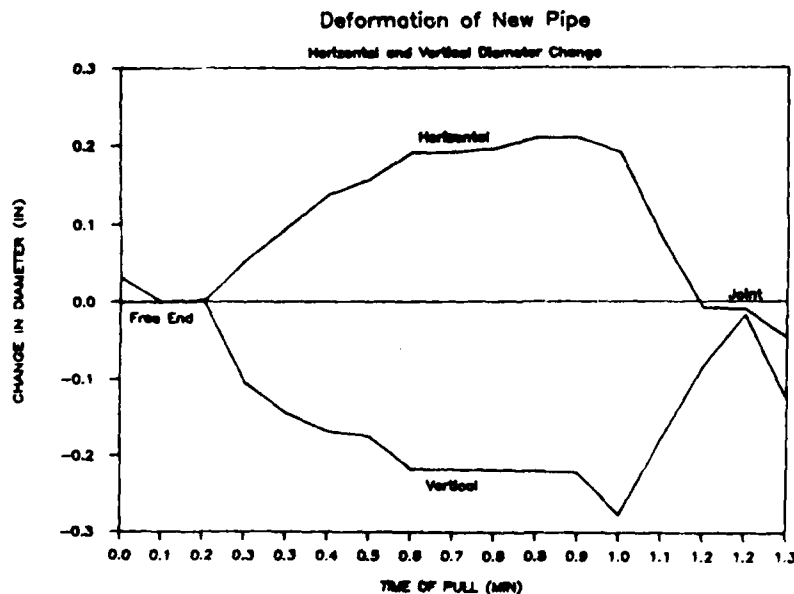


Figure 23. Deformation of inserted polyethylene pipe after installation. (Deformation is elliptical--described by relative changes in the horizontal and vertical diameter of the pipe.)

6 SELECTING A REHABILITATION TECHNIQUE

There is no panacea for sewer rehabilitation. It is important to understand which methods are appropriate for two reasons. First, a Facility Engineer must live with the results and needs to be able to reject bad advice. Second, the installation wants to get the best value for its investment. To accomplish this, one needs to have all appropriate technologies bidding against one another. A patented process should never be specified as THE rehabilitation technique, but rather, as one of several alternatives. The actual bid for rehabilitation will be based on a number of factors, including current workload of a contractor, market conditions, location, and method of construction. Therefore, to force the patented processes to bid against conventional processes, they should be listed as alternatives. If current workload and market conditions convince the patent holder the work is needed, royalties may be adjusted to compete with conventional processes, and conventional processes may adjust bids to compete with the innovative methods. If all alternatives are truly equivalent, then the least costly alternative is also the best value.

Figure 24 shows costs for three types of complete sewer line renovation. Grouting is not included because the cost is strongly related to the number of joints and cracks which must be repaired, whereas the three techniques shown in the figure renovate completely with a new pipe or liner. Grouting costs per crack or joint, updated to March 1987 (Engineering News Record [ENR] = 4356), range from \$20 to \$23 for 6-in. lines, and from \$130 to \$170 for 42-in. lines.³² PIM technology is not shown because there is insufficient data at this time. Predicted cost estimates for PIM technology are in the range from \$75 to \$135 per foot, for sizes ranging from 8 in. to 18 in. Thus, PIM is competitive only with the more expensive replacement situations.

Design, engineering, and construction management costs are not included in any of the cost curves. Costs not included in the cost curves for replacement sewers are bypassing wastewater, reconnecting services, traffic control, repaving, utility interference (existing utilities can slow work substantially as they require some hand excavation), and manhole rehabilitation/replacement. Costs not included for sliplining are preparation of access pits (cost depends on sewer depth and soil type), connecting services to the new liner, grouting the entire annular space, and bypassing wastewater.

Intangible costs are always difficult to equate to values for comparison with dollar costs, but should not go unconsidered. Closing a busy street does not cost the DEH anything, but it places a burden on installation personnel. Security is an Army-unique consideration which may weigh strongly towards use of "no-dig" technologies. Security concerns can range from traffic pattern changes through change in number, placement or operation of installation access, to undue exposure of communications lines.

Tables 5, 6, and 7 give the applications and limitations of chemical grouting, sliplining, and Insituform. Originally from *Utility Infrastructure Rehabilitation*, these three tables have been modified to include current information and to include hydraulic overloading as a structural problem. Table 8 gives the proposed applications and current limitations of PIM technology. To date, Insituform has been used for pipes up to 96-in., and PIM has been used, at maximum, to expand a 14-in. pipe to an 18-in. pipe.

³²*Utility Infrastructure Rehabilitation.*

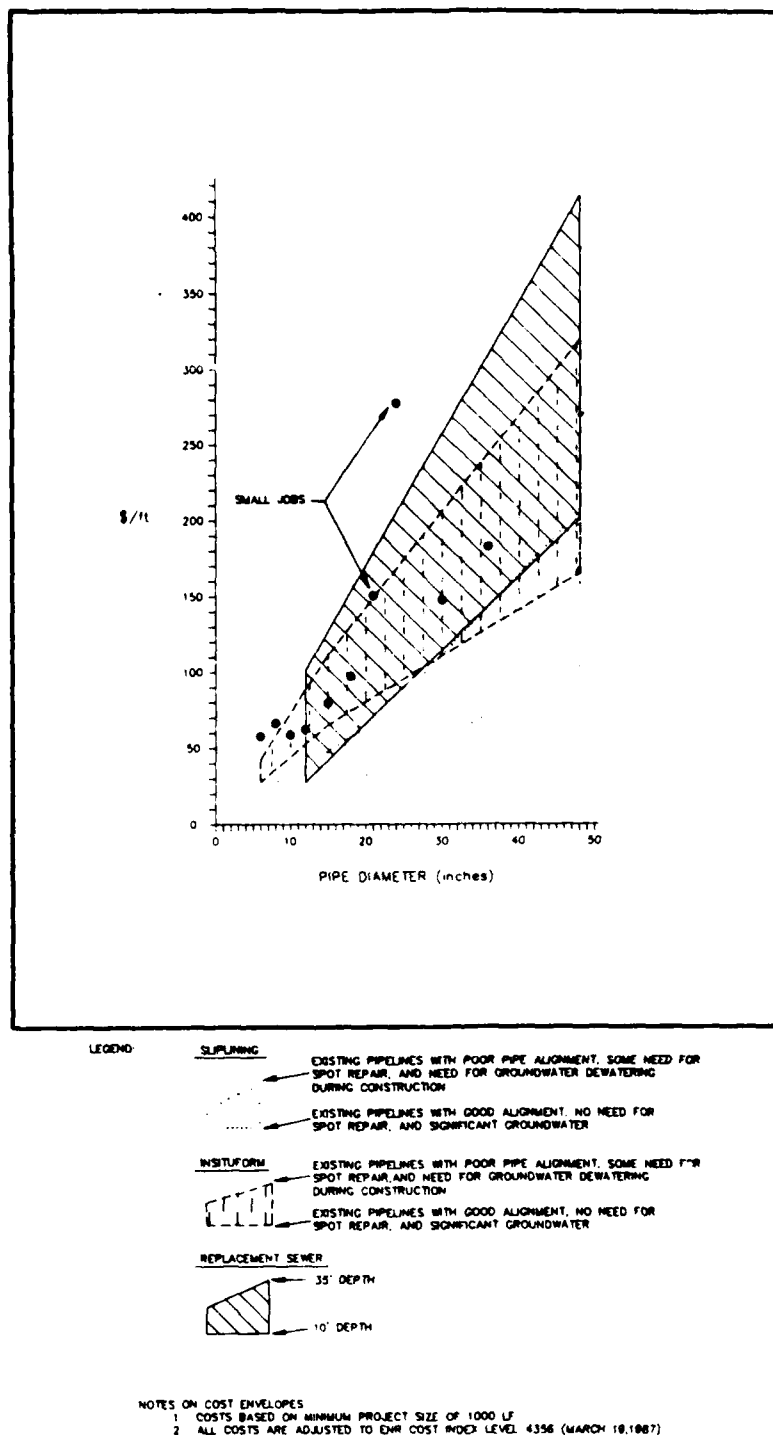


Figure 24. Comparison of cost for sewer rehabilitation. Job specific Insituform installation costs taken from *Insituform and Other Sewer Rehabilitation Techniques*, Thomas I. Simmons and Associates, EPA/600/2-85/132 (USEPA, November 1985). All costs based on data from *Existing Sewer Evaluation and Rehabilitation*, ASCE Manuals and Reports on Engineering Practice No. 62/WPCF Manual of Practice No. FD-6 (Lancaster Press, Inc. Lancaster PA, 1983).

Table 5
General Applicability of Chemical Grouting to Pipeline Problems

Condition	Remote Application*	Ability to Solve Problem**
Existing pipe size		
<6-in. diameter	No	NU***
6-in. to 42-in. diameter	Yes	U
>42-in. diameter	No	U
Existing pipe shape		
Circular	Yes	U
Irregular (i.e., ovoid, egg-shaped, horse-shoe, arched, etc.)	No	U
Structural problem		
Pipe crown or invert sag	-	NS
Reinforcing steel gone	-	NS
Reinforcing steel corroded	-	NS
Pipe joints deteriorated or open	-	CS
Pipe joints leaking or offset	-	CS
Pipe cracked	-	CS
Pipe crushed or collapsed	-	NS
Pipe cement corroded	-	NS
Pipe slabouts and holes	-	NS
Pipe hydraulically overloaded	-	NS

*Remote application using a packer system monitored by closed-circuit TV.

**These are general guidelines. Each structural problem in a particular pipeline must be examined by an expert. When a recommendation runs counter to these guidelines, the DEH should request a detailed explanation supporting the alternative chosen.

***Legend: U = Usable in this size range or pipe shape.
 NU = Not usable in this size range.
 CS = Conditional solution to this structural problem.
 NS = Does not solve this structural problem.

(Source: *Utility Infrastructure Rehabilitation* [Department of Housing and Urban Development, November 1984].)

Table 6

General Applicability of Insituform to Pipeline Problems

Condition	Remote Restoration* of Laterals	Ability to Solve Problem**
Existing pipe size		
<4-in. diameter	-	NU***
4-in. to 8 in. diameter circular pipe equivalent	No	U
8-in. to 72-in. diameter circular pipe equivalent	Yes	U
>72-in. diameter circular pipe equivalent	No	U
Existing pipe shape		
Circular	Yes	U
Irregular (i.e., ovoid, egg- shaped, horseshoe, arched, etc.)	Yes	U
Structural problem		
Pipe crown or invert sag	-	NS
Reinforcing steel gone	-	CS
Reinforcing steel corroded	-	CS
Pipe joints deteriorated or open	-	S
Pipe joints leaking or offset	-	CS
Pipe cracked	-	S
Pipe crushed or collapsed	-	NS
Pipe cement corroded	-	S
Pipe slabouts and holes	-	CS
Pipe hydraulically overloaded	-	NS

*Equipment for remote cutting for service restoration is currently not available for sizes less than 8 in. in equivalent circular pipe size. At sizes greater than 48 in. in equivalent circular pipe size, man entry for cutting is more efficient.

**These are general guidelines. Each structural problem in a particular pipeline must be examined by an expert. When a recommendation runs counter to these guidelines, the DEH should request a detailed explanation supporting the alternative chosen.

***Legend: U = Usable in this size range or pipe shape.
 NU = Not usable in this size range.
 S = Solves this structural problem.
 CS = Conditional solution to this structural problem.
 NS = Does not solve this structural problem.

(Source: *Utility Infrastructure Rehabilitation* [Department of Housing and Urban Development, November 1984].)

Table 7

General Applicability of Pipe Lining to Pipe Problems

Condition	Extruded Polyethylene ¹	Spiral-ribbed Polyethylene ²	Reinforced Extruded Polybutylene ³	Reinforced Plastic Mortar ⁴	Thermoset Resin ⁵	Ductile Iron ⁶ Cement Lined	Polyvinyl Lined
Existing Pipe Size							
<18 in. diameter	U ⁷	CUS	U	NU	U	CUC	CUC
18 in. - 33 in.	U	CUC	CUC	CUC	CUC	CUC	CUC
>36 in. diameter	CUS	CUC	CUC	CUS	CUS	CUS	CUS
Structural Problem							
Pipe crown or invert sag	S	S	S	S	S	S	S
Reinforcing steel gone	S	S	S	S	S	S	S
Reinforcing steel corroded	S	S	S	S	S	S	S
Pipe joints open or deteriorated	S	S	S	S	S	S	S
Pipe joints offset or leaking	CS	CS	CS	CS	CS	CS	CS
Pipe cracked	S	S	S	S	S	S	S
Pipe crushed or collapsed	NS	NS	NS	NS	NS	NS	NS

Table 7 (Cont'd)

Condition	Extruded Polyethylene ¹	Spiral-ribbed Polyethylene ²	Reinforced Extruded Polybutylene ³	Reinforced Plastic Mortar ⁴	Thermoset Resin ⁵	Cement Lined	Ductile Iron ⁶ Polyvinyl Lined
Pipe cement corroded	S	S	S	S	S	S	S
Pipe slabs and holes	S	S	S	S	S	S	S

¹ Available in nominal IPS diameters of 2 to 48 in.

² Available in actual inside diameters of 12 to 144 in.

³ Available in nominal IPS diameters of 12 to 144 in.

⁴ Available in nominal inside diameters of 18 to 66 in.

⁵ Available in actual inside diameters of 4 to 192 in.

⁶ Available in nominal IPS diameters of 4 to 60 in.

⁷ Legend: U = Usable in this size range.

CUS = Conditionally usable -- note maximum and minimum available liner size.

NU = Not usable in this size range.

CUC = Conditionally usable -- major capacity reduction must be acceptable

S = Solves this structural problem.

CS = Conditional solution to this structural problem.

NS = Does not solve this structural problem.

(Source: Modified from *Utility Infrastructure Rehabilitation* [Department of Housing and Urban Development, November 1984].)

Table 8

General Applicability of the Pipe Insertion Machine to Pipeline Problems

Condition	Remote Restoration* of Laterals	Ability to Solve Problem** (Nonductile Pipe Only)
Existing pipe size		
<4-in. diameter	No	U***
4-in. to 18-in. diameter	No	U
>18-in. diameter	No	NU
Existing pipe shape		
Circular	No	U
Irregular (i.e., ovoid, egg-shaped, horseshoe, arched, etc.)	No	NU
Structural problem		
Pipe crown or invert sag	-	S
Reinforcing steel gone	-	S
Reinforcing steel corroded	-	CS
Pipe joints deteriorated or open	-	S
Pipe joints leaking or offset	-	S
Pipe Cracked	-	S
Pipe crushed or collapsed	-	NS
Pipe cement corroded	-	S
Pipe slabouts and holes	-	S
Pipe hydraulically overloaded	-	S

*Equipment for remote cutting for service restoration is not practical for the PIM technology because the force from the mole destroying the pipe in place would be transferred axially along the lateral, causing severe structural damage.

**These are general guidelines. Each structural problem in a particular pipeline must be examined by an expert. When a recommendation runs counter to these guidelines, the DEH should request a detailed explanation supporting the alternative chosen.

***Legend:

- U = Usable in this size range or pipe shape.
- NU = Not usable in this size range.
- S = Solves this structural problem.
- CS = Conditional solution to this structural problem.
- NS = Does not solve this structural problem.

Open trench reconstruction is not included as a table: it can solve all problems since it is equivalent to new construction. The only drawbacks to open trench construction are cost and inconvenience. When selecting alternatives for rehabilitation, these tables should be consulted to determine which techniques are applicable. All acceptable alternatives should be used in competitive bidding. Combinations of alternatives should also be allowed. For example, open trench construction is the only method capable of repairing collapsed pipe. However, the collapsed pipe section can be treated as a point repair, in conjunction with sliplining, grouting, PIM, or Insituform for the remaining portion of the pipe.

Manhole and sewer lateral restoration are also important aspects of a wastewater collection system rehabilitation. The advantages and disadvantages of each method for manhole and lateral rehabilitation are listed in Tables 9 and 10.

Processes under development (stress-deformed HDPE and heat-deformed HDPE) as well as the proprietary processes of Weko-Seal and Rerounder were not included in the cost estimates. The processes under development have not had production application, thus it is too early to estimate costs. Costs for Weko-Seal and Rerounder may be obtained from licensees. Many other variations of technology are marketed under various tradenames which make the selection difficult for a Facility Engineer. Vendors of such variations on the technology should be able to describe in which class their technique falls. If claims outside the limits shown here for application or advantages/disadvantages are made, the burden of proof of such claims should be on the manufacturer. The best proof is successful, full scale demonstration, and is most acceptable when published by a user as a trade magazine article with technical descriptions. This allows the Facility Engineer to compare new processes or variations on existing processes.

Comparing the cost of work performed by installation personnel to work performed under contract is often difficult. Appendix D contains job reporting forms (from Thomas I. Simmons and Associates [EPA/600/2-85/132] with minor editorial modifications) which may aid in assigning costs to individual projects. This will help installation personnel develop cost comparisons between point repair and total rehabilitation, and develop actual workloads for commercial activity review. In addition, such checklists will be valuable references when further work is done in the future.

Table 9
Manhole Rehabilitation Methods
Advantages and Disadvantages

Method	Advantages	Disadvantages
Frame and Cover		
Stainless steel, neoprene washers or corks in holes in covers	Simple to install	Does not keep water from flowing through spaces around cover; does not allow venting
Prefabricated cover insert	Simple to install; prevents surface water sand, and grit from entering manhole through or around cover	Requires perfect fit for success
Joint sealing tape	Simple to install	- - -
Hydraulic cement	Provides strong, waterproof seal to stop infiltration	Labor-intensive; freeze-thaw cycle may reduce patch life
Raised frame	Minimizes inflow through cover and frame	Must be outside of street right-of-way
Sidewalls and Base		
Epoxy or polyurethane coatings on interior walls	Protects interior walls against corrosion; stops infiltration	Requires structurally sound manhole, surface must be very clean prior to application; surfaces must be dry prior to applying polyurethane coating
Chemical or clay grout	Can be very inexpensive method for stopping infiltration	Requires structurally sound manhole; cannot predict amount of grout required to eliminate infiltration
Structural liner	Repairs structurally damaged manholes; less disruption than replacement	Complex installation

(Source: *Utility Infrastructure Rehabilitation* [Department of Housing and Urban Development, November 1984].)

Table 10

**Lateral and Service Connection Rehabilitation Methods
Advantages and Disadvantages**

Method	Advantages	Disadvantages
Chemical Grouting		
Pump-Full	Can be used to grout main connections	Cannot predict amount of grout required; cannot grout very far up line; inefficient and expensive since grout is injected into whole line; must auger excess grout; estimated 5- to 10-year service life
Sewer Sausage	Uses less grout per foot than pump-full method.	Requires access to adequate cleanout; cannot predict amount of grout required; estimated 5- to 10-year service life
Lateral Sealing System	Does not require access to cleanout; uses less grout than pump-full method; air tests prior to grouting; can be used to grout main line connection.	Only tests and seals short lengths of lateral; estimated 5- to 10-year service life
Insituform	Provides some structural strength; provides integral, watertight pipe	Relatively expensive; positioning and sealing at ends is difficult; cutting end at main is difficult, requires access at cleanout.
Replacement	Provides new, watertight lateral	Expensive; requires extensive excavation

(Source: *Utility Infrastructure Rehabilitation* [Department of Housing and Urban Development, November 1984].)

7 SUMMARY

This technical report has addressed (1) conditions contributing to wastewater collection system deterioration, (2) techniques available and under development for rehabilitation, (3) tests of one new method, the Pipe Insertion Machine, and (4) issues in selecting a method and insuring the quality of its performance.

The major reasons for maintenance of collection systems are avoidance of blockages and disruptions of service and control of infiltration/inflow (I/I). Control of I/I offers cost savings to Army installations by reducing the capital and operating costs of Army operated wastewater treatment plants or by reducing costs from non-Army wastewater treatment plants which charge for treatment by volume.

Collection system deterioration is caused by the environment in which the piping resides (frost-heave, surface loading, root intrusion) and by the wastewater being collected (acid attack, crown corrosion) (Chapter 3). The rehabilitation technique should be matched to both the existing condition and the cause of deterioration. Over 50 percent of the installations which responded to the survey indicated using one or more of the common rehabilitation techniques. These techniques vary in their ability to restore structural stability and maintain hydraulic capacity.

Complete reconstruction of failed sewers creates substantial costs for surface restoration, trench digging, sheeting, and shoring. For these reasons, many new technologies are now available or are under development which do not require open trenches. Testing and grouting is a method for spot repairs which does not restore structural integrity (Table 5). Cement lining with steel can be used to restore structural integrity in large, man-entry sewers, but at the sacrifice of substantial hydraulic capacity (Table 7). Liners, principally polyethylene, can be inserted to improve structural integrity and provide a continuous, joint free pipe while losing approximately 10 percent of the cross-sectional area. New techniques (shrink-fit and thermally-deformed polyethylene) in liner preparation allow larger diameters to be inserted and more severe constrictions to be passed when using a lining technique. Insituform is a patented process for inserting a pliable liner of resin impregnated plastic, inflating it to conform to the existing pipe, and then curing the resin to a solid liner.

Another patented process, the pipe insertion machine (PIM), is capable of destroying the existing pipe in place and inserting a new high density polyethylene (HDPE) pipe of equal or larger diameter in its place. This process was tested by USA-CERL under an FTAT program at Fort Belvoir. The test results indicate that this technique does not produce large forces on the adjacent utilities and may have applications in highly developed areas which require increased hydraulic capacity.

The methods described here are not panaceas; some are useful only under rather specific conditions. Some factors which must be considered when choosing a rehabilitation method are the size and shape of pipe, the length needing repair, the pipe's structural condition, and intangibles such as disruption of surrounding traffic patterns. These must be compared to the methods' requirements and applicability (Tables 5 through 10) to determine the best match.

A sample SOW developed by EHSC and inspection checklists developed by Thomas I. Simmons and Associates (Appendices C and D) provide examples of the many issues that need to be considered when contracting for, inspecting, and documenting sewer rehabilitation.

REFERENCES

- Arbour, R. W., "Manhole Rehab Produces Results in Twin Cities," *Water Engineering and Management* (January 1985), Vol 132, No. 1, p 30.
- Brigham, A. P., "A Pipe Within a Pipe," *The Military Engineer*, No. 517, September-October 1987, p 544.
- Dorling, C., "Pipe Strain and Vibrations Caused by Percussive Moling: Site Experiment No. 2," Water Research Centre External Report No. 154E.
- Elmore, B. R., "Sealing Leaks that are Hard to Reach," *Public Works* (March 1984), Vol 115, No. 3, p 64.
- Existing Sewer Evaluation and Rehabilitation*, American Society of Civil Engineers Manuals and Reports on Engineering Practice No. 62 and Water Pollution Control Federation [WPCF] Manual of Practice No. FD-6 (Lancaster Press, Inc., Lancaster, PA, 1983).
- "Manhole Inserts Reduce Inflow 50 Percent," *Water Engineering and Management* (June 1984), Vol 131, No. 6, p 19.
- Poole, A. P., R. B. Rosbrook, and J. H. Reynolds, "Replacement of Small Diameter Pipes by Pipe Bursting," in proceedings of the No-Dig 85 Conference, "Trenchless Construction for Utilities," London, U.K., April 1985.
- Reed, K., "On Line Replacement and Microtunneling Techniques," Proceedings of the Pipeline Management 87 Conference, sponsored by Pipeline Industries Guild, Institution of Water Engineers and Scientists, Institution of Gas Engineers, and Institute of Petroleum; Confederation of British Industries Conference Center, Center Point, London, 12-13 February 1987.
- Reed, K., "The Application of Moling Techniques in the Water Industry," *No-Dig 87*, Proceedings of the Second International Conference, sponsored by the International Society for Trenchless Technology, Kensington Exhibition Center, London, 14-16 April 1987, pp 2.2.1-2.2.10.
- Sandaas, R. and M. C. Dirks, "Rehabilitation Planning, Design, Construction and Maintenance of the Metro Sewerage System in Seattle," presented at the ASCE Spring Convention, Seattle, WA, April 1986.
- Shrink-fit HDPE Liners for Water Mains and Sewers," *Water Quality International* (1987), No. 2, p 46, 1987.
- Soast, A. "Failing Sewer Saved by Jacking Pipe Through It," *Environmental News Record*, April 2, 1987, p 22.
- St. Onge, H., "Relining: The Feasibility of Inserting Pipe into Existing Sewers," *Canadian Water Resources Journal* (1984), Vol 9, No. 3, p 58.
- Steketee, C. H., *Demonstration of Service Lateral Testing and Rehabilitation Techniques*, EPA-600/2-85/131, NTIS No. PB86-135647 (USEPA, November 1985).

Sullivan, R., M. M. Cohn, T. J. Clark, W. Thompson, and J. Zaffle, *Sewer System Rehabilitation and New Construction*, EPA-600/2-77-017d, NTIS No. PB279248 (USEPA, December 1977).

Thomas I. Simmons and Associates, *Insituform and Other Sewer Rehabilitation Techniques*, EPA/600/2-85/132 (USEPA, November 1985).

Utility Infrastructure Rehabilitation (Department of Housing and Urban Development, November, 1984).

Winney, M., "Sewer Mole Cracks Into Steady Routine," *Underground*, July, 1986, p 18.

METRIC CONVERSION FACTORS

1 in. = 2.54 cm
1 ft = 0.3048 m
1 m = 1.609 km
1 psi = 0.06894 bar

APPENDIX A:

SEWER SYSTEM SURVEY FORM

Sewer System Rehabilitation Survey

Introduction: The Federal Water Pollution Control Act Amendments initiated many sewer rehabilitation projects aimed at reducing infiltration/inflow (I/I) and/or increasing hydraulic capacity. The purpose of this survey is to identify installations which have had such work performed, and to determine which methods are most effective in sewer rehabilitation.

Return this survey to: USA-CERL
ATTN: EN
P.O. Box 4005
Champaign, IL 61820-1305

Direct Questions to:
FTS: 958-7740
COMM: 800-USA-CERL

Installation Name _____ Location _____ MACOM _____
Name of Respondant _____ Phone # (FTS or COMM) _____

Sewered Area (acres or sq. mi.) _____ Population Served _____
Sewage flow (gpd) _____ % Domestic _____ % Industrial _____

Estimated Length (in lineal feet) of Collection System by Category:

Sanitary Sewer _____
Stormwater Sewer _____
Combined Sewer _____

What are the construction materials of the collection system?
(as a percent of total system)

Asbestos-cement	%	_____	Brick	%	_____
Cast Iron	%	_____	Concrete	%	_____
PVC Pipe	%	_____	Vitrified Clay	%	_____
ABS Pipe	%	_____	Other	%	_____

(ABS = acrylonitrile-butadiene-styrene)

Has an Infiltration/Inflow (I/I) study been performed at the installation? _____

If Yes, please indicate who performed the study in the space below:

Name: _____ Address: _____ Phone #: _____
() _____

Has sewer rehabilitation work been performed? _____

If yes, by whom?

Indicate methods used:

Name: _____	Grouting	_____
Address: _____	Slip lining	_____
	Insituform	_____
	Penettryne	_____
Phone #: () _____	Other (Describe)	_____

Please add any comments on your experiences with such rehab work on the back.

Thank You for Your Assistance in this Survey

APPENDIX B:

RESULTS OF SEWER SYSTEM SURVEY

Table B1
Survey Results for Sewer Construction Materials

Installation Name	Sewer Length	Cast Iron	Vitrified Clay	Concrete	Percent by Type					Galvanized Steel	Wood	ABS	Other
					Asbestos Cement	PVC	Steel	Wood	ABS				
Fort Bragg	1,824,766	4	45	10	6	2	0	0	13	0	0	20	20
Fort Benning	1,452,000	5	22	70	0	3	0	0	0	0	0	0	20
Fort Knox	880,400	0	94	0	0	2	0	0	0	0	0	0	0
Fort Riley	599,000	0	80	10	2	3	0	0	5	0	0	0	0
Fort Dix	531,982	0	90	0	0	10	0	0	0	0	0	0	0
Fort Belvoir	507,189	0	90	0	0	0	0	0	0	0	0	0	0
Fort Polk	502,000	2	60	1	2	35	0	0	0	0	0	0	0
Fort Leonard Wood	475,200	5	90	5	0	0	0	0	0	0	0	0	0
Fort Lee	410,197	2	80	18	0	0	0	0	0	0	0	0	0
Fort Carson	356,000	0	8	25	25	40	0	0	0	0	0	2	2
Fort Chaffee	346,424	0	90	10	0	0	0	0	0	0	0	0	0
Fort Sam Houston	329,160	1	50	40	0	5	0	0	2	0	0	2	2
Fort Eustis	316,800	30	40	20	10	0	0	0	0	0	0	0	0
Fort Rucker	294,500	2	45	50	0	3	0	0	0	0	0	0	0
Fort Richardson	203,304	0	0	85	15	0	0	0	0	0	0	0	0
Fort Benjamin Harrison	145,852	20	50	10	5	15	0	0	0	0	0	0	0
Fort Wainwright	134,053	5	0	0	60	0	30	0	0	0	0	0	0
Fort Drum	126,800	4	65	22	0	0	0	0	0	0	0	0	0
Fort Greely	80,230	0	0	0	90	10	0	0	0	0	0	0	0
Carlisle Barracks	41,399	6	24.5	50	0	6	0	0	0	0	0	14	0
Camp Bullis	23,200	15	40	40	0	5	0	0	0	0	0	0	0
Canyon Lake	3,100	0	95	0	5	0	0	0	0	0	0	0	0
Fort Ord	725,956	?	?	?	0	0	0	0	0	0	0	0	0
Fort Sheridan	119,159	?	?	?	0	0	0	0	0	0	0	0	0
Total (L.F.)	10,428,671	338,705	5,380,853	2,073,418	411,218	577,099	40,216	6,703	273,753	736,983	0.4%	2.9%	7.7%
Total of Percent Reported		3.5%	56.1%	21.6%	4.3%	6.0%	0.4%	0.1%					

APPENDIX C:

STANDARD STATEMENT OF WORK FOR INSPECTION AND REHABILITATION OF SEWER LINES

The following document was developed by the Engineering Division of USAEHSC. It is intended to be a comprehensive, generic Statement of Work which can be tailored to fit the project at hand and to meet the needs of inspectors, cost estimators, and specification writers.

The USAEHSC Point of Contact is Mr. Tom Wash, CEHSC-FU-S; telephone: COMM (703) 664-2077. Mr. Wash's address is USAEHSC, ATTN: CEHSC-FU-S/Tom Wash, Fort Belvoir, VA 22060-5516.

**STATEMENT OF WORK FOR INSPECTION AND
REHABILITATION OF SEWER LINES**

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Piping in Sewers

FOREWORD

This Statement of Work (SOW) is designed to help the inspector determine the condition of facility components, help the cost estimator develop the Government estimate for the proposed project, and help the specification writer develop and produce adequate specifications.

Part I is a checklist designed to assist the inspector in describing the condition of a facility component and provide a format for estimating quantity of work and cost. The checklist includes a set of definitions of technical and trade terms.

Part II discusses contracting methods and recommends appropriate Unit Price Schedule items.

Part III contains the SOW, which is written in a format that provides the specification writer with guidance for completing the SOW and leaves space for inserting notes to the contractors. The first two sections are general in nature and should be used in all contracts related to inspection and rehabilitation of sewer lines. The subsequent sections are written on specific, narrow topics and are intended to be used in conjunction with the general provision sections. It is recommended that SOW writers review completed checklists and project drawings, if any, and then select appropriate sections in Part III for use in preparing the final SOW.

PART I

CHECKLIST

- 1.0 Installation _____
- 1.1 Diameter of Pipe _____ Approximate Length _____

- 1.2 Pipe Material _____
- 1.3 Number of Service Connections _____ Depth of Water Table _____
- 1.4 Length of Sewer Below Water Table _____
- 1.5 Drawings and/or Specifications Available _____
- 1.6 Inspector _____ Date _____
- 1.7 Components of Collection System

<u>Component</u>	<u>Type</u>
Gravity _____	Industrial _____
Force Main _____	Domestic _____
Lift Station _____	Sanitary _____
Siphons _____	Storm _____
Sump Pump _____	Combined _____
Manholes _____	

CHECKLIST NOTES

- 1.0 Insert name of Army installation and state where the collection system is located.
- 1.1 Insert the pipe diameter in inches. Insert the approximate length of pipe in linear feet. Specify approximate length of pipe at the known pipe diameters.
- 1.2 Specify the pipe material used (e.g., vitrified clay, asbestos cement, cast iron, ductile irons, etc.).
- 1.3 Self explanatory.
- 1.4 Self explanatory.
- 1.5 Self explanatory.
- 1.6 Name of the individual making the precontract inspection and date of inspection.
- 1.7 Check () those items identifying the systems and equipment being used.

DEFINITIONS

1. AMMONIUM PERSULFATE ($\text{NH}_4)_2\text{S}_2\text{O}_8$

Properties: White crystals; strong oxidizing agent; soluble in water, Sp. gr. 1.98; m.p., decomposes. Low toxicity.

Derivation: Electrolysis of concentrated solution of ammonium sulfate. Recovered by crystallization.

Hazard: Strong oxidizing agent; dangerous fire risk when in contact with organic materials.

Uses: Oxidizing agent; used as an initiator to trigger the catalyst reaction in chemical sewer grout. Shipping regulations: (ICC, GC, IATA) Yellow label.

2. BOOSTER PUMP - Principal pump used in increasing the pressure of the water for cleaning the sewer line.

3. CABLE - A flexible shaft, capable of turning cutters at required torques and revolutions per minute.

4. CHEMICAL GROUTING - Method used to seal leaking joints in otherwise structurally sound, in-place sewer pipes. Special chemical compounds are used that either mix with soil particles, rendering them impermeable, or solidify in place, sealing the aperture.

5. CLEANING MACHINE - A portable device with a motor or engine used to propel a cutter or rod with appropriate fittings for attaching it to a cable.

6. CUTTERS - The actual cutting device comprised of a knife or saw edge, usually circular or spiral. Cutters are propelled by a cleaning machine.

7. DICHLOBENIL - Generic name for 2, 6-dichlorobenzonitrile: $\text{Cl}(\text{Cl})\text{C}_6\text{H}_3\text{CN}$.

Properties: White solid; m.p. 144 °C. Almost insoluble in water; soluble in organic solvents.

Hazard: Toxic by ingestion and inhalation.

Use: Herbicide, root inhibitor. Shipping regulations: (ICC, GC, IATA) Poison label.

8. EXCESSIVE INFILTRATION/INFLOW - The quantities of infiltration/inflow which can be economically eliminated from a sewer system by rehabilitation, as determined by a cost-effectiveness analysis that compares the cost for correcting the infiltration/inflow conditions with the total costs for transportation and treatment of the infiltration/inflow.

9. EXFILTRATION - The loss of liquid from a sewer into the ground through breaks, defective joints or porous walls.

10. **FEED CHUTE** - A small-diameter, round section used in inserting the cable into the inverts of manholes; with male and female end fittings (for joints); may be of rigid materials (as a pipe section) or flexible (as a hose).
11. **GROUTING** - General term indicating the method used to seal leaking joints in otherwise structurally sound, in-place sewer pipes.
12. **HYDRAULIC SCOURING** - Method of cleaning sediments, grime, and other extraneous matter from pipes by use of high pressure, high velocity water, or air and water by the use of a self-propelled nozzle.
13. **INFILTRATION** - The water entering a sewer system and service connections from the ground, through such means as, but not limited to, defective pipes, pipe joints, connections, or manhole walls. Infiltration does not include, and is distinguished from, inflow.
14. **INFILTRATION/INFLOW** - The total quantity of water from both infiltration and inflow without distinguishing the source.
15. **INFILTRATION/INFLOW ANALYSIS** - An engineering and, if appropriate, an economic analysis to evaluate possibly excessive infiltration/inflow.
16. **INFLOW** - The water discharged into a sewer system, including service connections, from such sources as, but not limited to, roof leaders, cellar, yard, and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas, manhole covers, cross connections from storm sewers and combined sewers, catch basins, storm waters, surface run-off, street wash waters, or drainage. Inflow does not include, and is distinguished from, infiltration.
17. **N, N'** - Methylenebisacrylamine: $\text{CH}_2(\text{NHCOCH}:\text{CH}_2)_2$.
 Properties: Colorless, crystalline powder; m.p. 185 °C. Sp. gr. 1.235 (30 °C).
 Hazard: Moderately toxic by ingestion.
 Uses: Organic intermediate, cross-linking agent.
18. **NOZZLE** - Specially built device which sends jets of water to the periphery of the pipe in the direction from which the nozzle is fed. Because of its own jet action it will travel in the direction opposite the jet.
19. **PLUG** - A flexible rubber device which is inserted into the pipe and inflated to stop the flow of fluids, so that work may be conducted in relatively dry conditions. Some plugs have metal ends where the air pressure hose is connected, and where a hose can be connected to allow liquid to be pumped from the pipe to a downstream location.
20. **RODDING TOOLS** - Devices of various designs and shapes used to clean and unplug pipes by removing stoppages, scraping the sides, or drilling through obstructions in order to restore the pipe to its full cross-sectional area.
21. **ROTARY CUTTER** - Device used to cut roots and other extraneous matter inside pipes to restore the full cross-section of the pipe area.
22. **SANITARY SEWER** - A sewer intended to carry only sanitary and industrial waste-waters from residences, commercial buildings, industrial plants, and institutions.

- 23. **SEAL PACKER** - Device used to inject grout into the apertures of pipe walls. Some packers have two rubber sleeves, others have three. The one to be used depends on the type of grout chemicals used and the particular application.
- 24. **SELF-DEVELOPING FILM** - Film for producing on-the-spot photographs, such as Polaroid (trademark of the Polaroid Corporation).
- 25. **STORM SEWER** - A sewer intended to carry only storm waters, surface runoff, street wash waters, and drainage.
- 26. **SUCTION PUMP** - Trash pump used in withdrawing the waste water generated in the cleaning process. These pumps should have constant speed and greater capacity than the booster pump. Suction pumps should be properly protected against cavitation.
- 27. **VIDEOTAPE RECORDING** - A method of recording television video signals on magnetic tape for later viewing.

PART II

CONTRACTING AND BID SCHEDULES

1. Sewer Line Inspection and Rehabilitation can be accomplished on a single or combined project basis.
2. Items for the Unit Price Schedule for a project specification may include the following:

<u>ITEM</u>	<u>QUANTITY/UNIT</u>	<u>UNITS</u>
a. Clean the following sewer lines by rotary cutter (schedule by manhole, size, type of pipe, and length)	—	LF*
b. Clean the following sewer lines by hydraulic scouring (schedule by manhole to manhole, size, type of pipe, and length)	—	LF
c. Clean the following sewer lines by rodding (schedule by manhole to manhole, size, type of pipe, and length)	—	LF
or		
d. Clean the following sewer lines by use of rotary cutter, hydraulic scouring or rodding (schedule by manhole to manhole, size, type of pipe, and length)	—	LF
e. Visually inspect the following quantities and sizes of sewer lines and manholes, including furnishing all equipment, protection and traffic control required; cleaning up and disposing of waste and debris resulting from the work; and submitting report:		
(1) Manholes (by diameter, depth in 2-foot increments, and method of inspection)	—	EA
(2) Sewer lines (by manhole to manhole, size and type of sewer line, and type of pipe material)	—	LF
f. Repair of manholes (by manhole number, depth and diameter)		
(1) Plaster, mortar or grout work in interior of manhole	—	EA

*LF = lineal feet; EA = each; CF = cubic feet.

<u>ITEM</u>	<u>QUANTITY/UNIT</u>	<u>UNITS</u>
(2) Mortar or grout work on manhole exterior		
(3) Dewatering	—	LS
g. Inspect the following quantities and sizes of sewer lines, using television inspection methods, including furnishing all material, equipment, protection and traffic control required; cleaning up and disposing of all waste and debris resulting from work; and furnishing report:		
(1) Sewer lines (by size and type of pipe material)	—	LF
(2) High flow sections of sewer line requiring bypass pumping (by size, type of pipe material, and minimum capacity in gpm of bypass pump and line required).	—	LF
h. Grout the following joints in sewer lines by size (schedule pipe sizes, pipe materials and type of joint):		
(1) VCP, Bell & Spigot	—	EA
(2) Grout service connection lines	—	LF
(3) Dewatering	—	LF
(4) Miscellaneous grouting	—	EA
i. Perform the following work for replacement of collapsed sewer piping including furnishing material and equipment, removing excess material, and cleaning up site:		
(1) Excavate trench (give dimensions)	—	CF
(2) Prepare bedding (give dimensions)	—	CF
(3) Install pipe (supply drawings)	—	LF
(4) Backfill trench (give dimensions)	—	CF

PART III

SPECIAL PROVISIONS FOR INSPECTION AND REHABILITATION OF SEWER LINES

NOTES:

Delete if not applicable.

1.0 GENERAL: The contractor shall comply with the sections entitled "Descriptions/ Specifications for Inspection and Rehabilitation of Sewer Lines" and the following "Specific Tasks and Standards:

...Visual Inspection of Sewer Lines and Manholes"
...Rodding of Sewers"
...Hydraulic Scouring of Sewers"
...Rotary Cutter Use in Cleaning Sewers"
...Television Inspection of Sewers"
...Sewer Line Grouting"
...Replacing Collapsed Piping in Sewers."

The SOW writer shall establish period of performance.

1.1 Period of Performance: Period of the performance shall be _____.

Installation may recommend other type contract and should so consider for recommendation to Contracting Officer.

1.2 Type of Contract: Firm-fixed Price.

Specify other data required for identification at the installation.

1.3 Administrative Provisions: The contractor shall furnish to the Contracting Officer promptly upon commencement of work under subject contract a written statement containing the complete names, addresses, and duties of each employee engaged in performing the work contemplated by this contract, together with such other data deemed necessary to establish the identity of each employee having access to Government buildings or facilities at the installation. In the event of a change in employees necessitated by illness, change in personnel, or other reason, the Contractor shall advise the Contracting Officer of the change and shall furnish him the name, address, and duty of the new employee prior to his/her arrival on the premises.

Delete portions if not required.

1.4 Preparations:

1.4.1 Protection: Inclusive of materials required to prevent damage to materials, equipment, fixtures, and finishings adjacent to worksite shall be the responsibility of the Contractor.

NOTES:

For site with critical traffic conditions, specify a specific traffic control schedule or hours of operation in specific areas, or both.

Omit paragraph where flows are low. When required, specify mandatory locations with pump line capacity.

Delete when disposal will be inside Government property.

Approved storage areas should noted in revisions.

1.4.2 Safety Equipment and Ventilation of Sewers: The Contractor shall provide safety equipment as necessary for the safety and health of personnel entering the manholes and sewers and proper ventilation shall be provided for personnel.

1.4.3 Traffic Control: The Contractor shall provide traffic control signs and furnish flagmen required to safely direct traffic at and around work areas. Traffic signs and locations shall be approved by the Contracting Officer and coordinated with the appropriate Traffic Control Officer.

1.4.4 Sewage By-Pass: Pump, temporary line and appurtenances to bypass sewage flow around section being inspected shall be provided. Alternate routing and discharge points shall be as approved by the Contracting Officer.

1.4.5 Permits and Approvals: If disposal of waste and debris generated in the performance of the work is to take place at points off Government property, the Contractor shall, prior to commencing the work, obtain and secure all necessary permits from local Government's health and sanitation officials where special approvals are required. Such approvals shall be obtained by the Contractor in writing prior to commencing the work.

1.5 Delivery and Storage: Materials shall be delivered to the site in an undamaged condition. Materials that are not installed upon delivery shall be stored in a safe, dry location and in a manner to prevent damage or loss. Materials damaged or lost before final inspection shall be replaced by the Contractor at no additional cost to the Government.

1.6 Quality Assurance: All services (which term throughout this clause includes services performed, material furnished or used in the performance of services, and workmanship in the performance of services) shall be subject to inspections and test by the Government to the extent practicable at all times and places during the term of the contract. All inspections by the Government shall be made in such a manner as not to unduly delay the work.

NOTES:

Specify job title of person designated for the installation. Specify frequency of meeting with COR.

Add specific instructions and requirements.

1.6.1 Contracting Officer Representative (COR): The work will be conducted under the general direction of the Contracting Officer and is subject to inspection by his appointed COR to insure strict compliance with the terms of the contract. No COR is authorized to change any provision of the specifications without written authorization of the Contracting Officer, nor shall the presence or absence of a COR relieve the Contractor from any requirements of the contract. The Contractor shall provide and maintain an inspection system acceptable to the Government covering the services to be performed hereunder. Records of all inspection work by the Contractor shall be kept complete and available to the Government during the term of this contract and for such longer period as may be specified elsewhere in this contract.

1.6.2 Responsibility for Quality Assurance Evaluation: The _____ is designated the COR. He or she may inspect work performed, make tests, and perform other functions of a technical nature not involving a change to the terms of the contract. Should it be found that the standards herein specified are not being satisfactorily maintained the Contractor shall immediately place the equipment, systems, and areas in conditions to meet these standards. The Contractor shall meet with the COR at regular intervals. These meetings will be held during normal business hours.

1.7 Data and Records: All data and records required shall be prepared by the Contractor in accordance with requirements of the Contract. In addition, the following items shall be accomplished by the Contractor:

1.7.1 Significant Items Notebook: The Contractor shall compile and continuously add to for each phase of the operation a Significant Items Notebook to record specific events encountered and actions taken during execution of tasks. The notebook will be available to all personnel. A copy of the notebook and update shall be provided to the COR when requested or as applicable.

NOTES:

1.7.2 Certificates of Compliance: Upon completion of work, the Contractor shall submit a certificate certifying that the sewer has been cleaned in compliance with specified requirements.

1.7.3 List of Obstructions: Upon completion of cleaning, the Contractor shall furnish a list of obstructions encountered. Distance and direction of obstruction from manholes shall be indicated.

1.7.4 Deviations: Upon completion of cleaning, the Contractor shall furnish a list of any deviations discovered between the contract drawings and the existing sewer lines.

Change or specify interface functions if different (requirements must be specific-include telephone numbers, names, etc.).

1.8 Interface With Other Functions: Maintenance and repair of utilities requires interruption of services and use of facilities for the duration of the operation. Therefore, the contractor shall maintain an effective working relationship and interface of responsibilities with installation organizations such as Chief of Utilities, Chief of Fire Department, and Sanitary Engineer. Requirements for services must be coordinated through the Contracting Officer or his designated representative.

Insert contract number and address of installation.

1.9 Marking instructions for all deliverable items by the Contractor shall be as follows:

**DESCRIPTION/SPECIFICATIONS FOR INSPECTION
AND REHABILITATION OF SEWER LINES**

NOTES:

Location of installation.
Specify boundaries by manhole
or street locations.

1.0 SCOPE. This specification covers the requirements for work to be performed on sewer lines to include cleaning, visual and television inspection, and rehabilitation. Specific requirements are covered by the applicable detailed specifications. A general emphasis is placed on cleaning as a prelude to inspection and rehabilitation. The contractor is required to provide for the physical inspection and regrouting of sewer lines located at _____ extending from _____ to _____
_____ to _____
_____ to _____.

1.1 General: The Contractor shall furnish all equipment, accessories, attachments, and parts necessary to accomplish the work. The equipment shall include but not be limited to the particular equipment specified.

2.0 Government Furnished Items: The Government shall provide maps and drawings of the existing sewer system.

3.0 Contractor Furnished Equipment: Materials and equipment not definitely specified shall be of a quality used for the purpose in commercial practice. All materials shall be clean, and free of defects, corrosion, and damage. All items shall be of proper type, size, design, and characteristics for the use intended. Equipment shall be in proper working condition, and shall be free of defects or malfunctions which may cause damage to existing work or delay of work. Unless otherwise specified, all items for repair or replacement shall be factory made and of domestic origin.

Delete paragraph if not
required.

3.1 Portable Cleaning Equipment: Equipment used in the cleaning of sewer lines shall be as specified, and as required to complete the work for the size, length, and conditions of the sewer. Portable and mobile equipment shall comply with Water Pollution Control Federation (WPCF) Manual of Practice (MOP) No. 7.

NOTES:

Change minimum number of each size plug required to shut off flow from lines entering upstream manhole if more than two is required; omit paragraph if plugs are available for a cleaning segment of the contract.

Check issue dates of standard publications and substitute latest issue if different.

3.2 Pipe Plugs: A minimum of two inflatable plugs shall be furnished for each size sewer. Each plug shall have heavy, corrosion resistant skids at each end to protect the inflatable and replaceable element from abrasive wear. Plugs shall be designed to use pressure of 40 psi and to withhold heads to 40 feet for 4-inch through 18-inch units and 20 feet for 21-inch through 36-inch units. An insertion pole fabricated in sections to allow plugs to be inserted into the sewer line from above ground level shall be furnished. The insertion pole shall be designed to hook securely to a plug for easy insertion and removal of the plug.

4.0 APPLICABLE PUBLICATIONS: The following publication of the issues listed below, but referred to thereafter by basic designation only, forms a part of this specification and supplementary detailed sections to the extent indicated by the references thereto:

Water Pollution Control Federation (WPCF)

Manual of Practice Sewer Maintenance
(MOP) No. 7

Department of the Army

Technical Manual Operation of Sewerage
(TM) 5-665 and Sewage Treatment
 Facilities at Fixed
 Army Installations

(TM) 6-666 Inspection and Preventive
 Maintenance Services -
 Sewage Treatment Plants
 and Sewer Systems at
 Fixed Installations

5.0 INSTALLATION:

Delete first sentence if only hydraulic scouring is specified. Delete if cleaning is not required.

5.1 Direction of Work: Sewer line cleaning work, with the exception of hydraulic scouring, shall proceed in the downstream direction. Cleaning by hydraulic scouring shall proceed in the upstream direction.

5.2 Manhole and Catchbasin Covers: Manhole covers shall be replaced upon completion of work in the immediate area.

NOTES:

Delete paragraph if sewer is to be inspected per television inspection specification.

Specify waste disposal sites. Large amounts of liquid waste may be screened and the liquid portion disposed of at a treatment plant and the solid portion at a sanitary landfill.

5.3 Testing: Upon completion of maintenance operation, sewer lines shall be tested for proper operation and shall be observed for a period of 24 hours. All stoppages observed shall be cleaned out and the line retested for proper operation.

5.4 Damage to Existing Sewer Line in the course of work, or caused by the process of work shall be reported in writing to the Contracting Officer. The report shall include location and extent of damage as well as probable cause of damage.

5.5 Waste and Debris resulting from the work shall be cleaned up and promptly removed from the work site at least daily and disposed of as specified. It should not be allowed to wash downstream and should be removed from the first downstream manhole. Debris shall not become a hazard to Government personnel or Government property. Disposal of waste and debris shall be at site specified.

**SPECIFIC TASKS AND STANDARDS FOR
VISUAL INSPECTION OF SEWER LINES AND MANHOLES**

NOTES:

- 1.0 **SCOPE:** This specification covers the specific requirements for visual inspection of sewer lines.
- 2.0 **EQUIPMENT:**
- Low voltage lamps are preferred.
- 2.1 Lamps shall be portable, flameless, and explosion-proof. Lamps shall be sufficient candle-power to enable proper inspection of sewers.
- Change the minimum quantity of each size plug to the minimum quantity required to shut off flow, if two such plugs are an inappropriate number. Omit paragraph if plugs are available from a cleaning segment of this contract.
- 2.2 Pipe Plugs: A minimum of two inflatable plugs shall be furnished by the Contractor for each size sewer requiring shutoff for inspection of manholes.
- 2.3 Air Supply: Supply for inflation of sewer plugs may be hand pump, air compressor, or air storage tank complete with air control regulator. Air supply shall be provided with a pressure gauge and an inflation hose of sufficient length to reach from air supply to bottom of deepest manhole. Air supply shall be capable of inflating plugs to at least 40 psi.
- 2.4 Photographic Camera and Color Film shall be provided to help in the identification and location of deficiencies.
- 3.0 **Procedure:**
- Delete if not necessary to clean before inspection can take place
- 3.1 Preliminary Cleaning: Sewer lines and manholes shall be cleaned as specified in this section as provided for in the "Description/Specification for Inspection and Rehabilitation of Sewer Lines," prior to performing visual inspection.
- 3.2 Inspection of Sewers: Personnel shall physically enter manholes for visual observation of sewer conditions. Conditions to be observed and recorded shall include, but not be limited to, root growth, sediments and types of sediment, structural conditions of pipe, alignment of pipeline, infiltration or inflow, stoppages, and any

NOTES:

other special problem or existing condition which is not normal or affects flow in any manner. Groundwater height over the pipe invert shall also be measured. Inspection shall be performed using lamps and mirrors in sewer lines between adjacent manholes, by not less than two experienced personnel, one being at each manhole.

3.3 Inspection of Large Sewers (30 inches or larger) shall consist of entering the sewer and inspecting all joints and pipes for structural condition, signs of leakage, root growth, sediments, cracks, signs of deterioration, or improper construction. Inspection of large sewers shall take place only after flows through the sewer have been stopped or diverted.

3.4 Inspection of Manholes shall include the observation and recording of the following information for each manhole scheduled for inspection:

- (a) Manhole identification.
- (b) Construction materials.
- (c) Condition of walls, plaster, corbel work, steps, aprons, flow channel, cover, and frame.
- (d) Manhole depth, barrel diameter, and frame diameter.
- (e) Location, diameter, and approximate flow, if any, of all pipe connections found that are not indicated on the sewer map.
- (f) Number and size of holes, if any, in manhole cover.
- (g) Visible infiltration sources and estimated flow rates.
- (h) Evidence of leaks and location.
- (i) Level of high water mark in manhole.

NOTES:

(j) Type and depth of debris

(k) Ground water depth at manhole for all manholes having ground water gauge installed in the manholes or installed in the ground adjacent to the manholes.

Add all known additional problems for the project site and delete those known not to exist.

Specify disposal site in General Provisions.

(1) Special problems and conditions, such as sources of inflow, overflow, bypass, and manholes located in natural ponding areas.

3.5 Cleanup: After each manhole and sewer line has been inspected and before moving on to the next section of work or leaving the site, all waste and debris shall be cleaned up and all damage, if any, resulting from the Contractor's operation shall be repaired or restored to the condition existing before such damage occurred.

3.5 Records of Inspection:

3.6.1 Record of Inspection of Sewers shall include the deficiency, as well as the approximate location and distance from the downstream manhole. Photographic records shall be provided whenever applicable.

If photographs of all manholes having questionable conditions are not desired, delete last two sentences. If only one type of photograph is desired, delete inapplicable type. If prints from 35 mm negative are desired, delete slides and add prints and the size of prints required.

3.6.2 Recording: Information specified in the paragraph entitled Inspection of Manholes (3.4) shall be recorded on a data sheet for manhole inspection. A separate shall be used for each manhole scheduled for inspection. Photographs of each manhole having questionable conditions shall be taken for subsequent review and included in the report to be submitted to the Contracting Officer. The photographs shall be self-developing film prints or 35 mm slides.

3.7 Conclusions and Recommendations: Conclusions of existing conditions and deficiencies and their probable causes, as well as recommendations for further cleaning or repairs shall be made by experienced personnel.

3.8 Report and Certificate of Compliance:

NOTES:

Fill in the schedule of sewers to be inspected using a separate line for each section of sewer between two manholes.

Best time for inspection is early morning hours. Provide schedule of sewers, and the time of day in which the inspection will not disrupt normal site activities. Add a DATE OF INSPECTION column when date of inspection should be specified to minimize disruptions. Delete paragraph if not required.

3.8.1 Upon completion of the work, a complete inspection report including photographs shall be submitted to the Contracting Officer as specified. Data sheets for sewer and manhole inspection shall be completed by the Contractor and included in the report.

3.8.2 The Contractor's inspection report shall be accompanied by a certificate of the Contractor stating the extent of the inspection made and that the sewer lines and manholes have been inspected by the Contractor in compliance with specified requirements.

4.0 EXTENT OF INSPECTION:

4.1 Physical Dimensions: The Contractor shall perform a complete inspection of the following sections of sewer in the sequence of the following schedule approved by the Contracting Officer.

4.2 Time and Duration of Inspection shall be limited to the times specified. Any line inspection not completed during one of the allowed periods shall continue at a later approved time, until the inspection is completed and complies with the specifications.

Schedule order should minimize disruption of normal site activities.

FROM MH	TO MH	LINE SIZE	LINE LENGTH	REMARKS
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SPECIFIC TASKS AND STANDARDS FOR RODDING OF SEWERS

NOTES:

Delete provision if not applicable.

1.0 **SCOPE:** The requirements of this section supplement those contained in specifications pertaining to Preliminary Cleaning (3.1) in the "Specific Tasks and Standards for Visual Inspection of Sewer Lines and Manholes."

2.0 EQUIPMENT:

2.1 Cleaning Machine shall be power operated, variable speed, and of the required horsepower. Cleaning machine shall have a manually-controlled, powered cable feeder.

2.2 Cable shall be of the proper length and design and shall be marked in 1-foot intervals. Cable shall have proper fittings, as required for adding more cable length.

2.3 Rodding Tools shall be of the proper design for the individual circumstance and shall be of the proper size to suit the inside diameter of the sewer line.

2.4 Feed Chute shall be of the length and size required for insertion of cable through manhole invert. Chute shall originate at the cleaning machine and extend not less than 2 feet into the pipe to be cleaned.

2.5 Cable Joints: The first cable joint, and that which is closest to the cleaning machine, shall be a universal joint. All other points shall be secured with a pin or cotter pin and restricted in torsional movement.

3.0 PROCEDURE:

3.1 Cleaning: Rod and cable shall be inserted in the pipe at invert of manhole, in the downstream direction, attached to cable and machine, and the interior of the pipe rodded until all obstructions are removed.

3.2 Observation: Effects of cleaning shall be observed at downstream manhole.

3.3 Flushing: Upon completion of the rodding operation, the sewer line shall be flushed. All materials 2 inches or larger in any direction shall be removed.

SPECIFIC TASKS AND STANDARDS FOR HYDRAULIC SCOURING OF SEWERS

NOTES:

Delete provision if not applicable.

1.0 SCOPE: The requirements of this section supplement those contained in the general specifications pertaining to Sewer Line Cleaning in the General Provisions for Inspection and Rehabilitation of Sewer Lines.

2.0 CLEANING EQUIPMENT:

2.1 Booster Feed Pump shall be centrifugal, variable speed, of proper flow and head characteristics, electric power or engine driven, with maximum speed of 1750 rpm.

2.2 Tubing and Piping: Flexible tubing and piping shall be of the lengths and sizes required with joints which will keep the amount of leakage to a minimum. Joints for flexible tubing shall be survival-type to avoid excessive twisting and possible pinching. All tubing and piping shall be secured in place during course of work, and protected against traffic damage.

2.3 Nozzle: Flushing nozzle shall be backward delivery type, with a circular jet of water acting on the full inside periphery of the pipe. Nozzle shall not be of the rotating type. Nozzle may deliver water continuously or in surges.

2.4 Suction Pumps used in removing waste and debris washed by nozzle action shall be of a capacity equal to or greater than the booster feed pump. It shall be a nonclog type, with self-priming capabilities, and with proper protection against cavitation by means of recirculation or other means.

2.5 Pipe Plugs shall be inflatable type, and shall stop all flows from passing in either direction at high static heads and shall be of the proper size stated in General Provisions.

Delete paragraph if water is to be furnished by the Government.

2.6 Water: Contractor shall furnish water to be used in the cleaning operation. Potable water supply shall not be used unless an approved backflow preventer is provided for the crossconnection.

NOTES:

If sewer is sanitary, upstream pipes may also be plugged if flows are small, or if work is conducted during low flow periods.

Delete "flowing up service connections and overflowing catch basins" if not applicable.

Location for disposal of waste and debris shall be stated in general provisions. Since this waste is of a liquid nature, it may be discharged at the head of a treatment plant.

Delete if paragraph is not required.

2.7 Accessories required to complete the work shall be provided by the Contractor.

3.0 PROCEDURE:

3.1 Pipe plug shall be inserted and inflated at downstream pipe to avoid waste and debris entering downstream portion of sewer.

3.2 Cleaning: Interior walls of pipe shall be scoured with high pressure water through nozzle.

3.3 Pressure Control: Water pressure shall be controlled to avoid water overflowing at manholes, flowing up service connections, and overflowing at catch basins.

3.4 Collection of Washwater: Washwater containing waste and debris shall be collected through the use of the suction pump at the same manhole where nozzle was inserted, when operation is in the upstream direction.

3.5 Disposal of Washwater and Waste: None of the washwater containing waste and debris shall be disposed of or discharged in any form at ground level, or the streets, in ditches, canals, rivers, or in same or adjacent sewers. All spills shall be contained, removed, and cleaned up immediately after occurrence.

3.6 Recirculation of Water: Water used in hydraulic scouring shall be screened and recycled in order to minimize the supply amount.

**SPECIFIC TASKS AND STANDARDS FOR
ROTARY CUTTER USE IN CLEANING SEWER LINES**

NOTES:

1.0 SCOPE: The requirements of this section supplement those contained in the general provisions pertaining to sewer line cleaning in the Description/Specifications for Inspection and Rehabilitation of Sewer Lines.

2.0 CLEANING EQUIPMENT:

2.1 Cleaning Machine: Power operated, variable speed, and of required horsepower. Cleaning machine shall have manually controlled powered cable feeder.

2.2 Cable shall be of the proper length and design and marked at 1-foot intervals. Cable shall have proper fittings as required for adding more cable length.

2.3 Cutters shall be of the proper design for the individual circumstances, shall be sharp, and shall be of the proper size to suit the inside diameter of the sewer line.

2.4 Feed Chute shall be of the length and size required for insertion of cable through manhole invert. Chute shall originate at the cleaning machine and extend not less than 2 feet into the pipe to be cleaned. Feed chute shall have its own stands and supports.

2.5 Cable Joints: The first cable joint and that which is closest to the cleaning machine shall be a universal joint. All other joints shall be secured with a pin or cotter pin and restricted in their torsional movement.

3.0 PROCEDURE:

3.1 Cleaning: Cutters shall be inserted in pipe at invert of manhole, in the downstream direction, attached to cable and machine, and interior of pipe shall be reamed until all obstructions are removed.

3.2 Observation: Effects of cleaning shall be observed at downstream manhole.

3.3 Flushing: Upon completion of the cutting operation, the sewer line shall be flushed. All materials 2 in. or larger in any dimension shall be removed.

SPECIFIC TASKS AND STANDARDS FOR TELEVISION INSPECTION OF SEWERS

NOTES:

Delete if either the specific time for inspecting each sewer line or progress schedule is specified elsewhere.

Delete last sentence if instant replay is not required.

Still photographic record may be specified to be self-developing, 35 mm slides, or prints. If prints are desired, specify minimum size.

Two hand winches may be substituted for very small inspection projects only.

Omit night operation lighting if this capability is not required. Omit control room lights, heat and air, if smaller trailer unit is to be employed rather than truck mounted unit.

1.0 SCOPE: This specification covers the specific requirements for television inspection of sewer lines.

2.0 SUBMITTALS: Before commencing the work the Contractor shall submit to the Contracting Officer for approval a progress schedule showing the starting and completion dates for inspection of each sewer line.

3.0 EQUIPMENT:

3.2 Television Camera: A closed circuit TV having an ultrawide (60 degree minimum) angle lens, specially designed to observe the conditions in sewer lines shall be used.

3.3 Monitor: A high resolution TV monitor screen shall be utilized.

3.4 Videotape equipment shall be utilized to record the sewer inspection and display the camera location. The equipment shall have instant replay capability.

3.5 Still Photographs: Still camera equipment shall be used to provide photographs taken from the TV monitor with self-developing or 35 mm film.

3.6 Winches: Variable speed, powered, remote controlled winches shall be used for upstream and downstream manhole locations to control two-way movement of the camera.

3.7 Footage Meter shall be used for recording the location of defects.

3.8 Power Supply: A generator with adequate power for the components specified plus auxiliary night operation lighting and air conditioning, heating, and lighting of the control/monitoring room shall be used.

NOTES:

Omit paragraph if air compressor for air testing is specified elsewhere in the same contract.

Add additional accessories required, if any, for special or unusual conditions.

Omit inapplicable subparagraphs.

Consult DOD Construction Criteria Manual 4270.1M for specific noise levels. Specify maximum dB that will be permitted.

Actual time or days may be specified.

Modify by omitting float line and winches if television inspection will be done in conjunction with hydraulic scouring where camera can be transported by scouring nozzle and hose. Specify bypass pump and alternate routing line to bypass section to be inspected if system flows are high at time of inspection.

3.9 Air Supply: An air supply for inflation of sewer plugs shall be used. Air supply may be a hand pump, air compressor, or air storage tank complete with air control regulator. Air supply shall be provided with a pressure guage, and an inflation hose of sufficient length to reach from air supply to bottom of deepest manhole. Air supply shall be capable of inflating plugs to at least 40 psi.

3.10 Pipe plugs of the pneumatic type as per "Description/Specifications for Inspection and Rehabilitation of Sewer lines," (3.2).

3.11 Mats or all-terrain type vehicles shall be used for use where sewers are in swampy or soft areas adjacent to water.

3.12 Residential type silencers shall be used where sewers are near hospitals and other noise critical areas.

4.0 PROCEDURE:

4.1 General: Television inspection of the sewer system shall begin at the specified starting point and time, proceed in compliance with the schedule of work, and be completed in compliance with the progress schedule approved by the Contracting Officer.

4.2 Positioning Equipment: The truck or trailer shall be parked at the upstream manhole facing away from the section of sewer to be inspected.

4.3 Inserting Camera: Float and line shall be inserted at upstream manhole and line floated through section to be inspected. Upstream plugs shall be inserted to cut off flow. Winches and manhole guides shall be positioned at upstream and downstream manholes. Winch cable shall be pulled through section and TV camera connected. Winch cables and television transmission cables must be in manhole guides.

NOTES:

Omit inflow if not desired.

Omit infiltration/inflow quantifying when this will be performed at a later time from the videotape.

Omit paragraph if service defects are not to be included in contract.

If no flows are being discharged from the building, it may be assumed that the observed flow is infiltration or inflow. If the

4.4 Inspection Procedure: During the inspection, the camera shall be stopped at locations where one or more of the following conditions are observed:

- (a) Infiltration/inflow sources;
- (b) Service connections;
- (c) Structural defects, including broken pipe, collapsed pipe, cracks, deterioration, punctures, and the like;
- (d) Abnormal joint conditions, such as horizontal and vertical misalignments, open joints, and joints not fully seated; and
- (e) Unusual conditions, such as root intrusion, protruding pipes, inline pipe size changes, mineral deposits, grease, and obstructions.

4.4.1 All such conditions as specified above shall be recorded. Photographs of all questionable conditions shall be taken for subsequent review. The photographs shall be taken from the TV monitor with self-developing or 35 mm films. All infiltration/inflow sources shall be quantified while observing through the TV monitor. The infiltration/inflow sources shall be recorded with videotape for flow estimation and for later review. Before taking the photographs or videotape, the TV camera shall be properly positioned so that the optimum view of the defects, deficiencies, and other undesirable conditions can be obtained. If necessary, the same problem object shall be viewed from the opposite direction by pulling the TV camera from the other manhole in the sewer section. For reference purposes, photographs and videotapes of typical sewer sections and joints in lines being inspected shall also be taken.

4.4.2 At the connecting points between the service connections and the sewer being inspected, the TV camera shall be stopped to check for any flows coming out of the service connections. Whenever a flow is observed, its source shall be checked out immediately. The building to which the service connection is connected shall be checked first for any wastewater discharge during the inspection.

NOTES:

estimated flow from the service connection is greater than the total wastewater discharged from the fixtures in the building, the infiltration/inflow may be determined by calculating the difference of these two flows.

This information is essential for conducting the cost-effectiveness analysis and for planning a sewer rehabilitation program. Modify if any items listed (e.g., recommendation of corrective action and quantifying of infiltration/inflow) are not to be filled in.

Fill in the schedule of sewers to be inspected using a separate line for each section between two manholes (e.g., section from manhole 4 to manhole 5 of one line and the section between manhole 5 and manhole 6 on another line). Schedule order should minimize disruption of normal site activities in the area of work including rerouting of traffic and sewage flow. Add an

4.4.3 The locations of the conditions recorded shall be identified by recording the distance from each defect or point of interest to an established point in each sewer section, such as from the center of the starting manhole to the plane of focus of the camera.

4.4.4 Recording and Reporting Deficiencies: For each section of sewer inspected, a television inspection log sheet shall be completed and submitted to the Contracting Officer upon completion of the work. A separate line of the log sheet shall be used for each deficiency located.

All applicable blanks on each log sheet shall be filled in by the Contractor. In addition to the columns for recording the footage, observations, and infiltration/inflow rates, the sheet shall include columns for recording the recommended corrective action and the photograph number. The recommended corrective action for each pipe or infiltration/inflow source shall be based on the conditions of the defect or the type of infiltration/inflow source. The photographs shall be numbered and the photograph number for each item shall be correspondingly recorded on the log sheet.

5.0 EXTENT OF INSPECTION: The Contractor shall perform a complete television inspection of the following sections of sewer in the sequence of the following schedule and within the time schedule approved by the Contracting Officer.

NOTES:

"Hours of Inspection" column
for projects where flows or
traffic will only permit
inspection during certain hours
of the day or night.

NOTES:

UPSTREAM MANHOLE	DOWNSTREAM MANHOLE	LINE SIZE
1	2	18"
2	3	18"
3	4	18"
4	5	18"
5	6	18"
6	7	18"
7	8	18"
8	9	18"
9	10	18"
10	11	18"
11	12	18"
12	13	18"
13	14	18"
14	15	18"
15	16	18"
16	17	18"
17	18	18"
18	19	18"
19	20	18"
20	21	18"
21	22	18"
22	23	18"
23	24	18"
24	25	18"
25	26	18"
26	27	18"
27	28	18"
28	29	18"
29	30	18"
30	31	18"
31	32	18"
32	33	18"
33	34	18"
34	35	18"
35	36	18"
36	37	18"
37	38	18"
38	39	18"
39	40	18"
40	41	18"
41	42	18"
42	43	18"
43	44	18"
44	45	18"
45	46	18"
46	47	18"
47	48	18"
48	49	18"
49	50	18"
50	51	18"
51	52	18"
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62	63	18"
63	64	18"
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67	68	18"
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91	92	18"
92	93	18"
93	94	18"
94	95	18"
95	96	18"
96	97	18"
97	98	18"
98	99	18"
99	100	18"

LINE	LENGTH	REMARKS
1	100	100
2	100	100
3	100	100
4	100	100
5	100	100
6	100	100
7	100	100
8	100	100
9	100	100
10	100	100
11	100	100
12	100	100
13	100	100
14	100	100
15	100	100
16	100	100
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98	100	100
99	100	100
100	100	100

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SPECIFIC TASKS AND STANDARDS FOR SEWER LINE GROUTING

NOTES:

Check issue dates of standard publications and substitute latest issue if different on this and following pages.

1.0 SCOPE: This provision covers the specific requirements for sewer line grouting.

2.0 APPLICABLE PUBLICATIONS: The following publications of the issues listed below, but referred to thereafter by basic designation only, form a part of this specifications to the extent indicated by the references thereto:

American National Standards Institute
(ANSI)

A118.3-1968 Epoxy Mortar

American Society for Testing and Materials

(ASTM)

C476-71 Mortar and Grout for Reinforced
Masonry

3.0 SUBMITTALS:

3.1 Manufacturer's Product Data shall include grout application to specific problems and the recommended proper solution. Information shall include:

3.1.1 Application to type of joint; recommended practice.

3.1.2 Application to surrounding soil materials; recommended practice.

3.1.3 Application to ground water; recommended practice.

3.1.4 Recommended method of grout mixing, handling, pumping, injecting, curing, removing.

3.1.5 Solubility in water, viscosities, recommended mixing ratios and additives.

3.1.6 Chemical resistance table, including effects of pH.

3.1.7 Particle size distribution of grout.

Particle size distribution is important if grout is the gel-forming type.

NOTES:

Specify approved storage areas in the general provisions.

Consider other types of sewer line rehabilitation when soil is not sand or sandy loam with particle size between 0.075 and 0.1 mm.

Acrylamide gel is most widely used, but it should be compatible with existing field conditions.

3.2 Certificates of Compliance:

3.2.1 Manufacturer shall certify that the grout materials comply with specifications and when applied under recommended procedures, grout shall perform in compliance with specifications.

3.2.2 Contractor shall certify that all methods, equipment and conditions of application shall be carried out in compliance with the specifications and the grout manufacturer's recommendations.

4.0 DELIVERY AND STORAGE: Materials shall be delivered to the site in an undamaged condition. Materials that are not installed upon delivery shall be stored in a safe, dry location and in a manner to prevent damage or loss. Materials damaged or lost before final inspection shall be replaced by the Contractor at no additional cost to the Government.

4.1 Chemicals, Grout, and Admixtures shall be stored above floor level in original containers, and protected against extreme heat, cold, and water damage.

4.2 Fragile Materials and Equipment shall be shipped with proper shock insulation and protected against damage due to direct blows, vibration, crushing, or accidental dropping. No small parts shall be packed with fragile items, but shall be packed and shipped separately. All containers shall be clearly marked "fragile."

5.0 MATERIALS AND EQUIPMENT:

5.1 Grout shall be as specified, applicable to sewer conditions, as required to seal the pipe from leaks. Type of grout used shall be compatible with the soil and moisture conditions and shall provide watertight seals under all internal and external conditions to which the sewer shall be subjected.

5.1.1 Acrylamide gel shall be an aqueous solution of acrylamide and N,N' methylene-bisacrylamide powders, with the proper catalyst, such as B-dimethylaminopropionitrile and ammonium persulfate, mixed in the proper proportions and concentrations to achieve the desired results, depending on the field conditions. Reaction or gel time, mixture

NOTES:

Delete paragraph if not required.

Delete paragraph if not required. Epoxy mortar is used for hand applications, especially in large sewers.

Delete 5.1.5 if root growth is not a problem. If roots are protruding, then they must first be cut.

Omit paragraph when grout proposed does not require separate mix tanks.

concentrations, and catalyst shall be as recommended by the grout manufacturer based on the temperature and other field conditions at the time of use. A gel time of approximately 20 seconds shall be used unless recommended otherwise by the manufacturer. For locations subject to wet-dry cycles, chemical additives shall be added to prevent dehydration of the grout gel.

5.1.2 Polyurethane foam grout shall be an aqueous solution of liquid urethane polymer, with a water-soluble amine accelerator, at the concentrations recommended by the manufacturer to achieve the desired results.

5.1.3 Epoxy mortar grout shall comply with ANSI A118.3.

5.1.4 Portland cement grout shall comply with ASTM C476.

5.1.5 Root Growth Inhibiting Additives, recommended by the grout manufacturer, such as 0.1 percent dichlobenil, shall be added to the grout material in adequate quantities as recommended to inhibit root growth.

5.2 Grout Packer shall consist of a hollow metal cylinder with two inflatable rubber sleeves, one at either end, with the hose and cable fittings, as required to do the work. The packer shall rest on sleeves, and shall be of the proper size for the diameter of the sewer, and designed for joint and crack grouting. Packer shall have proper hose connections for grout feed and return lines, air lines for sleeve inflation and air testing and pulling cable connection.

5.3 Grout Pump shall be of the proper design to deliver grout or grout mixtures at varying capacities, pressures, and viscosities as recommended by the grout manufacturer.

5.4 Plant: Grout mixing plant shall have the necessary equipment and accessories for proper mixing and storage of components to suit the type of grout used.

5.5 Mix Tanks: Separate mix tanks shall be provided as recommended by the grout manufacturer.

NOTES:

5.6 Hoses for chemical grout, catalyst, and air shall be provided.

5.7 Flow Meters shall be provided to record the volume of chemical grout and catalyst pumped at each leak repair.

5.8 Closed Circuit Television Camera and Monitor shall be of the size and type required to view the location of the grout packer with respect to joints or other crevices.

5.9 Air Compressor shall be of sufficient capacity as to effect 4 psi internal pressure per 100 feet of sewer to be tested.

6.0 PREPARATION:

Delete this paragraph if sewers do not require preparatory cleaning.

TV inspection is preferred.

6.1 Preparatory Cleaning: Prior to beginning of grouting work, sewers to be repaired shall be cleaned of all debris, sediments, and tuberculation.

6.2 Sewer Line Inspection: Sewer line shall be thoroughly inspected during grouting, and obstructions or places where grouting is not feasible shall be identified.

7.0 INSTALLATION:

Cleaning can be accomplished using a rodding machine and a hydraulic scourer.

7.1 Cleaning of Sewer shall be done to remove obstructions to the passage of the packer and remove extraneous materials from locations which will be grouted. All organic material shall be removed from sewer.

7.2 Locating Packer shall be done with the aid of a television camera attached behind the packer at a distance which will allow the operator to judge location of the packer in relation to the pipe joint.

NOTES:

Air testing may be employed in lieu of simulating ground-water conditions. Air testing may be done by the grouting. Determination of the need for repair of a joint which loses a minimal amount of pressure during the test period depends on the conditions and the significance of the leak.

Delete paragraph if lateral grouting is not required. Where excavation is not a problem, shallow service laterals often may be excavated and replaced at less cost. (Other, newer methods are discussed in Chapter 4 of main text.)

This method is especially applicable to manholes. Delete paragraph if not applicable.

Specify only one of the "Testing of Grouted Sewers" subparagraphs.

7.3 Grouting: Once the packer has been positioned properly, the rubber sleeves of the packer shall be inflated until they expand and seal against the pipe wall on both sides of the joint. The joint shall be air tested to determine its integrity. Once it is determined that grouting for the joint is required, the grout shall be pumped in sufficient and pressure to seal all openings which allow water. A record shall be kept of the amount of used at each location and the pressure reached in process of grouting. Joints shall be identified for purposes by recording the downstream and manholes and the distance from the downstream manhole in feet. Records shall be submitted to the Contracting Officer. Grout shall be allowed to set, the packer sleeves shall be deflated, and the work inspected with the television camera. The joint shall be air tested. Joints requiring further grouting shall be regouted, or other repairs shall be made to provide watertight conditions. Grouting shall take place at all joints determined to require repair and at cracks and crevices where infiltration or exfiltration is occurring or has a possibility of occurring.

7.4 Grouting of Lateral Connections and Manhole External Drops shall consist of pumping grout to fill the entire length of the lateral pipe and manhole drops until the grout exfiltrates through the various leaks. Allowing for proper grout setting time, the grouted pipe shall be reamed of excess grout in its entirety. All excess grout shall be removed without being discharged in the main sewer and disposed of properly.

7.5 Manual Grout Application: Large sewers allowing the physical entrance of personnel shall be grouted using the probe-type application and injecting the grout material directly in the leaks or through holes drilled at the leaks. Grouting shall continue until all leaks are stopped.

7.6 Testing of Grouted Sewers:

7.6.1 Air testing of each individual joint and crevice shall be conducted prior to and upon setting of the Delete paragraph 7.6 if in-place grout. Joints maintaining pressure shall not be another method of testing be grouted. Test time

NOTES:

shall be determined in compliance is employed. with ASTM C828-80 ("Recommended Practice for Low-Pressure Air Test of Vitrified Clay Pipe Lines [4 to 12-in.]) with proper conversions made for the length of pipe tested. The test shall be for not less than 30 seconds at each location, at pressures greater than or equal to the hydrostatic head caused by the maximum expected groundwater elevation. Air will be pumped into the test volume to 4.0 psi and will be allowed to stabilize for 2 to 5 minutes. When pressure has stabilized at greater than or equal to 3.5 psi, the test will commence. Pressures shall be recorded at each location at 5 second intervals with an accuracy of 0.05 psi. Locations having pressure drops due to air leaks greater than or equal to 1.0 psi over the calculated test time shall be repaired using grout or another approved method, until all leaks are stopped. Location shall be retested after repairs are made.

7.6.2 Hydrostatic Testing: Upon completion of grouting a section of sewer, the line shall be hydrostatically tested for leaks. Leaks shall be repaired using grout or another approved method, until all leaks are stopped. Line section shall be retested after repairs are made.

Performance of work shall be specified in lieu of other means of determining leakage. Specifier may indicate a leakage other than 100 gpidm but it should never be greater than 250.

7.6.3 Performance of Grouted Sewers: Grouted sewer lines shall have no more than 100 gallons per inch diameter per mile (gpdm) of sewer per day infiltration or exfiltration, upon completion of the work. The infiltration test may be used when the ground water is at least 2 feet higher than the pipe crown. Leakage shall be measured with a weir. The exfiltration test shall consist of plugging successive upstream manholes and service connections and filling of line from the upstream manhole with water to a depth of 2 feet or more above the pipe crown or the ground water, whichever is higher. Sections of sewers experiencing more than the allowable leakage shall be regouted or otherwise repaired by approved methods.

SPECIFIC TASKS AND STANDARDS FOR REPLACING COLLAPSED PIPING IN SEWERS

NOTES:

When replacing pipe "to match existing," if more than one type of piping is encountered in the same line, all replaced piping should be of publications compatible material which must be specified.

Check issue dates of standard publications and substitute latest issue if different.

1.0 SCOPE: This provision covers the specific requirements for the replacement of asbestos-cement and vitrified clay pipe in open channel sewers.

2.0 APPLICABLE PUBLICATIONS: The listed below, referenced thereafter by basic designation only, form a part of this specification and supplementary detailed sections to the extent indicated by the reference thereto.

American Association of State Highway and Transportation Officials (AASHTO)

T180-74 Moisture - Density Relations of Soils
Using a 10 lb (4.5 kg) Rammer and an 18 in.
(457 mm)

American Society for Testing and Materials

C33-86 (ASTM) Specification for Concrete Aggregates

C425-77 Specification for Compression Joints
for Vitrified Clay Pipe and Fittings
Revised 1982)

C428-81 Specification for Asbestos-Cement
Nonpressure Sewer Pipe (ASTM, Revised 1985)

C498-65 Specification for Perforated Clay Drain
Tile (Revised 1981)

C663-83 Specification for Asbestos - Cement Storm
Drain Pipe

C700-78 Specification for Vitrified Clay Pipe, Extra
Strength, Standard Strength, and Perforated

D1869-78 Specification for Rubber Rings of Asbestos -
Cement Pipe Revised 1983)

D2564-85 Specification for Solvent Cements for
Poly (Vinyl Chloride) (PVC) Plastic Pipe
and Fittings

NOTES:

Water Pollution Control Federation (WPCF)

MOP No.9 Design and Construction of Sanitary Storm Sewers

3.0 SUBMITTALS:

3.1 Certificates of Compliance: Notarized certificates of compliance from the manufacturer shall be submitted to the Contracting Officer for approval. Certificates on pipe material shall certify compliance with the applicable publications listed herein.

4.0 STORAGE AND HANDLING OF PIPE: Shall be in compliance with manufacturer's recommendations. No chains, cables, or hooks in pipe ends shall be used.

5.0 MATERIALS:

Delete type of pipe which does not apply. Other pipes may be substituted as per specific requirements.

5.1 Pipe shall be of the type, size, thickness, and design required to comply with drawings and specifications.

Reference WPCF MOP No. 9.

5.1.1 Pipes shall be perforated vitrified clay and shall comply with ASTM C498.

5.1.2 Pipe shall be regular vitrified clay and shall comply with ASTM C700.

5.1.3 Small diameter nonpressure pipe of asbestos-cement (up to 6 inches) shall comply with ASTM 644.

5.1.4 Large diameter nonpressure pipe of asbestos-cement (greater than 8 inches) shall comply with ASTM C428.

5.1.5 Storm drain pipe shall comply with ASTM C663.

Delete those which do not apply.

5.2 Fittings for vitrified clay pipe shall be regular vitrified clay, strength to match existing, and comply with ASTM C700.

5.3 Joints:

5.3.1 Compression joint sealing element for vitrified clay pipe shall comply with ASTM C425 and be of rubber, plastic, or metal.

5.3.2 Asbestos-cement joints shall be rubber ring seal joints and shall comply with ASTM D1869.

NOTES:

5.3.3 Solvent cement shall comply with ASTM D2564.

6.0 PREPARATION:

6.1 Materials shall be examined to make certain they comply with the specifications.

6.2 Cleaning: Prior to the start of repair work, dirt and grime or any other material which might hamper sealing will be removed from pipe and fittings.

7.0 PROCEDURE:

7.1 Excavation and Trenching

7.1.1 Trenches, manholes, and utility cuts shall be of the necessary width and depth for manholes and the proper laying of pipe. The banks shall be as nearly vertical as practicable. Make all excavations by open cut. Excavate trenches no wider than that which will provide an 8 inch clearance on each side of the utility at top of pipe and 12 inch clearance around manholes. Perform all excavations of whatever substance encountered to the depths shown or indicated. If unsuitable or unstable soil is encountered, remove and replace with gravel, crushed stone, or slag and thoroughly tamp.

Specify approved materials in special provisions.

7.1.2 Trench Bottom shall be accurately graded to provide uniform bearing and support the entire length of the pipe. Excavate bell holes after trench has been graded. Trench bottom shall be smooth and free of sharp objects. When trench bottom is unstable, it shall be over-excavated for at least one and one-half pipe diameters and replaced with approved materials. Where hard rock is encountered, the trench bottom shall be over-excavated to a depth of six inches and replaced with approved materials.

In past, dewatering has led to many protests. Any dewatering requirements should be very carefully written if groundwater levels are variable or unknown.

7.1.3 Dewatering: Water shall be removed from excavations and the trench kept dry during installation of piping and during backfilling operations.

7.2 Bedding:

Pipe shall be checked for the requirement of cathodic protection.

7.2.1 Bedding material shall be washed, natural sand or gravel containing no vegetable matter or thin, elongated particles, and shall comply with ASTM C33.

NOTES:

Omit material not readily available in the project area.

Clays and mixtures of clay, sand, and gravel are cohesive soils: sands and gravels are cohesionless soils.

7.2.2 Installation: Bedding shall be placed by hand in 3 inch layers and compacted by tamping so as to provide continuous bearing and support for the pipe at every point. Each layer shall be compacted to not less than 95 percent of maximum density at optimum moisture in compliance with AASHTO T180.

7.3 Backfill:

7.3.1 General: Density of backfill shall be determined in compliance with AASHTO T180.

7.3.2 Backfill material shall consist of clays, sands, gravels, and/or mixtures thereof, or other approved material free from large clods of earth, stones greater than 1 inch, debris, frozen materials, roots and other organic materials.

7.3.3 Backfilling shall commence after reconnections have been completed and all forms, trash, and excess mortar have been removed.

Backfill shall not be placed in wet or frozen areas. Moisture content of backfill material shall facilitate compaction. Backfill shall be compacted to the required density with suitable tampers.

7.3.3.2 Lower Portion of Trench: Backfill shall be deposited in 6 inch layers until there is a cover of not less than 1 foot over the pipe. The backfill material shall be free from stones larger than 3 inches in any dimension. If any portion of the cover in the lower portion of the trench is in the depth of subbase, subgrade, or ballast under pavements or railroads, the requirements of subbase, subgrade, or ballast shall control.

7.3.3.3 Remainder of Trench: Except for subbase, subgrades, or ballast for pavements and railroads the remainder of the trench shall be backfilled with material that is free of stones and clods of earth larger than 6 inches or half the layer thickness, whichever is smaller, in any dimension. Backfill material shall be deposited, in layers not exceeding the thickness specified, and each layer shall be compacted to the minimum density specified as applicable to the particular area.

NOTES:

7.3.4 Degree of compaction shall be as follows, expressed as a percentage of the maximum density obtained by the test procedure presented in AASHTO T180:

7.3.4.1 Under Railroads, Roads, and Paved Areas: 6 inch layers, 90 percent maximum density for cohesionless soils.

7.3.4.2 Under Turfed or Seeded Lawn Areas and Sidewalks: 12 inch layers, 85 percent maximum density for cohesive soils and 90 percent maximum density for cohesionless soils.

7.3.5 Finishes: After backfilling, trenches and manholes shall be graded to conform to adjacent contours. If trenches or manholes are improperly filled or if settlement occurs, voids shall be refilled and redressed.

Specify approved equipment in special provisions.

7.3.6 Equipment: Compaction shall be obtained using approved equipment of the proper size and type for the work areas, materials being compacted, and compaction required.

7.3.7 Compaction test shall be made by an approved testing laboratory with the results documented and certified, and with copies in duplicate sent to the Contracting Officer within 24 hours of completion of test.

7.3.8 Field Testing Control: Testing shall be the responsibility of the Contractor and shall comply with AASHTO T180. Test results shall be furnished to the Contracting Officer. When test results indicate that compaction is not as specified, the material shall be removed and replaced or recompacted to meet specification requirements at no expense to the Government. Subsequent tests on recompacted areas shall be performed to determine compliance with specification requirements.

8.0 INSTALLATION:

Delete first sentence if existing buried pipe is to be abandoned in place and to be replaced in a slightly different location.

8.1 Existing Piping to be Replaced shall be removed and the new piping installed in the same location as the piping replaced. Piping shall be cut accurately and shall be worked into place without springing or forcing. Open ends shall be properly capped or plugged to keep dirt and other foreign material out of the system. Pipe shall have burrs removed by reaming. Changes in direction shall be made with fittings, except that bending

NOTES:

of steel pipe will be permitted, provided a hydraulic pipe bender is used. Bent pipe showing kinks, wrinkles, or other malformations will not be acceptable. Mitering of pipe to form elbows, and notching of straight runs to form tees will not be permitted.

Indicate grade of pipe on drawings.

8.2 Installation of Underground Pipe: Pipe shall be graded as indicated. Joints in steel pipe shall be welded except as herein permitted for installation of valves. Where the trench has been over-excavated, it shall be backfilled with suitable material and thoroughly tamped to provide full length bearing. Supporting pipe on blocks to produce uniform grade will not be permitted.

Delete inapplicable paragraphs.

9.0 TESTING: To be performed as outlined in "Specific Tasks and Standards for Grouting of Sewer Line."

Reference other tests compatible with pipeline materials as desired.

APPENDIX D:

REHABILITATION JOB REPORTING FORMS

These forms are reproduced with some modifications from Insituform and other Sewer Rehabilitation Techniques, EPA/600/2-85/132, by Thomas I. Simmons and Associates (published by USEPA, November 1985).

Personnel responsible for contract supervision or long-range planning may find these or similar forms useful for comparing the costs of different methods, for doing detailed evaluation of the work, and for documenting the work for future reference.

Collecting detailed information such as that requested by the forms can help insure that correct and effective rehabilitation measures are taken.

Inspector's Checklist - Sewer Grouting (1 of 4)

INSPECTOR'S NAME _____

CONTRACTOR'S NAME _____

DATE _____ WEATHER _____

EFFECT OF WEATHER _____

LOCATION _____

EST. HT. OF WATER TABLE ABOVE INVERT AT TIME OF INSPECTION _____

LOCATION OF SEWER

☐ AS-PAVT ☐ FL-LAWN ☐ DW-GRAV ☐ SW-BTOP
☐ BS-PAVT ☐ RL-LAWN ☐ DW-STOP ☐ PW-PWAY
☐ PC-PAVT ☐ SL-LAWN ☐ SW-CONC ☐ UK-OTHER
☐ GR-ROAD ☐ DW-CONC ☐ SW-BRCK DESCRIBE UK OTHER _____

M.H. NO. _____ to M.H. NO. _____ DISTANCE _____

M.H. REHABILITATION (IF ANY)

M.H. No.	DIA.	DEPTH	MATERIAL	TYPE OF REPAIR
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

TILE TYPE

☐ VT ☐ CI
☐ PL ☐ ST
☐ CO ☐ OT
 DESCRIBE OTHER _____

TILE SIZE _____ IN DISTANCE BETWEEN JTS. _____

AVE. FLOW DEPTH _____ IN. AVE. SEWER DEPT: _____ FT.

ROOT GROWTH	TYPE OF DEPOSITS	DEPTH OF DEPOSITS
<input type="checkbox"/> HEAVY	<input type="checkbox"/> GRAVEL <input type="checkbox"/> SLUDGE	_____ IN.
<input type="checkbox"/> MOD	<input type="checkbox"/> SILT <input type="checkbox"/> BITUMINOUS	
<input type="checkbox"/> LIGHT	<input type="checkbox"/> DETERGENT <input type="checkbox"/> MISC.	
<input type="checkbox"/> NONE	DESCRIBE MISC. _____	

TYPE OF CLEANING Date _____
PERFORMED

☐ NONE ☐ HIGH PRESS FLUSH
☐ RODDING ☐ ROOT CUTTING
☐ BUCKETING ☐ OTHER
☐ OTHER (DESCRIBE) _____

VISIBLE INFILTR/EXFILTR.
SOURCES

☐ ROOTS ☐ SERVICES
☐ OFFSET JTS. ☐ DETERIORATED
☐ CRACKED TILE JT. MATERIAL
☐ OTHER (DESCRIBE) _____

Inspector's Checklist Sewer Grouting (2 of 4)

() BUCKETING () ROOT REMOVAL-CHEMICAL () OFFSET JTS. () OTHER
 () OTHER () CRACKED TILE
 DESCRIBE OTHER _____

COMMENTS _____

POINT REPAIRS REQUIRED PRIOR TO SEALING (GROUTING)

STA	DIA	DEPTH	WET OR DRY		MAT'L USED	FOOTAGE REPL	SVC. CONN	REASON
			W	D				
_____	_____	_____	()	()	_____	_____	_____	_____
_____	_____	_____	()	()	_____	_____	_____	_____
_____	_____	_____	()	()	_____	_____	_____	_____
_____	_____	_____	()	()	_____	_____	_____	_____
_____	_____	_____	()	()	_____	_____	_____	_____

COMMENTS _____

_____ BYPASSING REQUIRED () Y () N REASON IF YES _____

DATE _____
 PERIOD OF BYPASSING: FROM _____ TO _____

TOTAL TIME OF BYPASSING _____

METHOD OF BYPASSING _____

EQUIPMENT REQUIRED _____

TIME AND DATE INDIVIDUAL SEWER SERVICE TERMINATED _____

TIME AND DATE INDIVIDUAL SEWER SERVICE REINSTATED _____

TOTAL TIME OUT OF SERVICE _____

TOTAL NUMBER OF SERVICES THIS SECTION _____

WAS IT REQUIRED TO LOCATE UTILITIES () Y () N

IF YES EXPLAIN _____

TRAFFIC CONTROL REQUIRED

() LANE CLOSURE NO. OF LANES _____	TOTAL TIME REQUIRED _____
() TOTAL STREET CLOSURE _____	TOTAL TIME REQUIRED _____
() FLAGMAN AND SIGNING ONLY _____	TOTAL TIME REQUIRED _____
() NONE _____	

REMARKS _____

Inspector's Checklist Sewer Grouting (3 of 4)

PRE-GROUTING INTERNAL INSPECTION-VIDEO TAPE REP. NO. _____

JOINTS: () PULLED PIPE: () SAGS
 () OFFSET () RADIAL CRACKS
 () CRACKED () LATERAL CRACKS
 () ROOTS () DEPOSITS
 () INFILTRATION () BROKEN PIPE
 () EXFILTRATION

SPECIAL REQUIREMENTS _____

PRE-GROUTING VISIBLE M.H. INFILTRATION () YES () NO

SERVICES	SIZE	REASON
NO. _____ NO. REPL./REPAIRED _____	_____	_____
SIZE _____	_____	_____
NO. ACTIVE _____ NO. INACTIVE _____	_____	_____
SERVICE ROOTS () Y () N FROM STA _____ TO STA _____	_____	_____
NO. FACTORY WYES OR TEES _____ NO. TAPS _____	_____	_____
NO. OF PROJECTING TAPS _____ STA. OF PROJECTING TAPS _____	_____	_____

WAS T.V. RE-SET REQUIRED () Y () N REASON _____

REMARKS _____

GROUTING

NO. OF JOINTS TO BE GROUTED; PLAN _____ ACTUAL _____
 TOTAL NO. OF JOINTS IN SECTION _____ TYPE OF JOINTS _____
 METHOD OF TESTING JOINTS _____
 TESTING CRITERIA _____
 EQUIPMENT USED _____
 TYPE OF SEALING MATERIAL USED _____
 TIME AND DATE STARTED _____
 TIME AND DATE COMPLETED _____
 TOTAL TIME REQUIRED _____
 AVERAGE TIME PER JOINT _____

POST-GROUTING;

TV INSPECT - COMMENTS _____

COST OF REHABILITATION

PREPARATORY CLEANING (INC. ROOT REMOVAL)	\$ _____
INTERNAL INSPECTION (PRE)	\$ _____
INTERNAL INSPECTION (POST)	\$ _____
BYPASS PUMPING	\$ _____
POINT REPAIRS	\$ _____
TEST AND SEAL JOINTS	\$ _____
TEST LINE	\$ _____
SURFACE RESTORATION	\$ _____
TOTAL	\$ _____

Inspector's Checklist Sewer Grouting (4 of 4)

COMMENTS REGARDING EFFECTS TO ENVIRONMENT OF WORK _____

INSPECTOR'S GENERAL REMARKS. THIS SHOULD COVER ANY ITEMS WHICH THE INSPECTOR
FEELS ADDED TO THE SUCCESS OF THE REHABILITATION, CAUSED PROBLEM DURING RE-
HABILITATION OR WOULD BE HELPFUL TO THE REVIEWER IN EVALUATION OF THE REHABILITA-
TION PROCESS AND RESULTS.

Inspector's Checklist Sewer Insituform (1 of 4)

INSPECTOR'S NAME _____
 DATE _____ WEATHER _____
 ADDRESS OF SEWER _____

EST. HT. OF WATER TABLE ABOVE INVERT AT TIME OF INSPECTION _____

LOCATION OF SEWER

() AS-PAVT () FL-LAWN () DW-GRAV () SW-BTOP
 () BS-PAVT () RL-LAWN () DW-STOP () PW-PWAY
 () PC-PAVT () SL-LAWN () SW-CONC () UK-OTHER
 () GR-ROAD () DW-CONC () SW-BRCK DESCRIBE UK OTHER _____

M.H. NO. _____ to M.H. NO. _____ DISTANCE _____

TILE TYPE

() VT () CI
 () PL () ST
 () CO () OT
 DESCRIBE OTHER _____

TILE SIZE _____ IN DISTANCE BETWEEN JTS. _____
 AVE. FLOW DEPTH _____ IN. AVE. SEWER DEPT: _____ FT.

ROOT GROWTH	TYPE OF DEPOSITS	DEPTH OF DEPOSITS
() HEAVY	() GRAVEL () SLUDGE	_____ IN.
() MOD	() SILT () BITUMINOUS	
() LIGHT	() DETERGENT () MISC.	
() NONE	DESCRIBE MISC. _____	

TYPE OF CLEANING PERFORMED	Date _____	VISIBLE INFILTR/EXFILTR. SOURCES
() NONE () HIGH PRESS FLUSH		() ROOTS () SERVICES
() RODDING () ROOT CUTTING		() OFFSET JTS. () DETERIORATED
() BUCKETING () OTHER		() CRACKED TILE JT. MATERIAL
() OTHER (DESCRIBE) _____		() OTHER (DESCRIBE) _____

METHOD OF BYPASSING _____
 EQUIPMENT REQUIRED _____
 TIME AND DATE BYPASSING STARTED _____
 TIME AND DATE BYPASSING STOPPED _____
 TOTAL TIME OF BYPASSING _____
 TIME AND DATE INDIVIDUAL SEWER SERVICE TERMINATED _____
 TIME AND DATE INDIVIDUAL SEWER SERVICE REINSTATED _____
 TOTAL TIME OUT OF SERVICE _____
 TOTAL NUMBER OF SERVICES THIS SECTION _____

TRAFFIC CONTROL REQUIRED

() LANE CLOSURE NO. OF LANES _____	TOTAL TIME REQUIRED _____
() TOTAL STREET CLOSURE _____	TOTAL TIME REQUIRED _____
() FLAGMAN AND SIGNING ONLY _____	TOTAL TIME REQUIRED _____

REMARKS _____

Inspector's Checklist Sewer Insituform (2 of 4)

TIME REQUIRED TO ERECT SCAFFOLD

HEIGHT OF SCAFFOLD ABOVE GROUND _____ FT.

HEIGHT OF SCAFFOLD ABOVE SEWER INVERT _____ FT.

SOURCE OF INVERSION WATER

() F.H. PUBLIC WATER SUPPLY

() PUMPER TRUCK

() SURFACE WATER

REMARKS (SPECIAL PROBLEM, ETC.) _____

BAG LENGTH _____ FT.

BAG THICKNESS _____ MIL. NO OF LAYERS _____

BAG WETTED DOWN OFFSITE ()

TIME AND DATE BAG WETTED _____ (A.M.) (P.M.)

TIME AND DATE INVERSION STARTED _____ (A.M.) (P.M.)

TIME AND DATE INVERSION COMPLETED _____ (A.M.) (P.M.)

TIME AND DATE CIRCULATION STARTED _____ (A.M.) (P.M.) INITIAL TEMP _____

TIME AND DATE 180°F TEMPERATURE REACHED _____ (A.M.) (P.M.)

TIME AND DATE COOL DOWN STARTED _____ (A.M.) (P.M.)

TOTAL TIME FROM START OF CIRCULATION TO 180°F _____

TOTAL TIME FROM WET DOWN OF BAG TO START OF COOL DOWN _____

HEAT EXCHANGER BTU OUT BTU/HR. _____

ESTIMATE CIRCULATION RATE _____ GPM

PRE-INSITUFORM INTERNAL INSPECTION VIDEO TAPE REF. NO. _____

JOINTS: () PULLED PIPE: () SAGS
 () OFFSET () RADIAL CRACKS
 () CRACKED () LATERAL CRACKS
 () ROOTS () DEPOSITS
 () INFILTRATION () BROKEN PIPE
 () EXFILTRATION

PRE INSITUFORM VISIBLE M.H. INFILTRATION () YES () NO

SERVICES

NO. _____

SIZE _____

NO. ACTIVE _____

SERVICE ROOTS _____

NO. FACTORY WYES OR TEES _____

NO. TAPS _____

NO. OF PROJECTING TAPS _____

NO. SERVICES REQUIRING DIG-UP PRIOR TO LINING _____

REMARKS _____

Inspector's Checklist Sewer Insituform (3 of 4)

POST-INSITUFORM INTERNAL INSPECTION VIDEO TAPE REF. NO. _____

LINER

PIPE INVERT; () SMOOTH PIPE WALLS; () SMOOTH
() WRINKLED () WRINKLED

REMARKS _____

CHANGE IN SUBSIDENCE OF BROKEN PIPE

REMARKS _____

NO. OF SERVICES REINSTATED _____

AVE. TIME TO CUT OUT SERVICE _____

COST OF REHABILITATION

PREPARATORY CLEANING (INC. ROOT REMOVAL)	\$ _____
INTERNAL INSPECTION (PRE)	\$ _____
INTERNAL INSPECTION (POST)	\$ _____
BYPASS PUMPING	\$ _____
POINT REPAIRS	\$ _____
INSITUFORM CONTRACT COST	\$ _____
TEST LINE	\$ _____
SURFACE RESTORATION	\$ _____
TOTAL	\$ _____

Inspector's Checklist Sewer Insituform (4 of 4)

TIME AND TEMPERATURE RECORD.

THE TIME AND TEMPERATURE SHALL BE RECORDED AT 15-MINUTE INTERVALS AT FOUR DEFINITE LOCATIONS. THE INSPECTOR SHALL ALSO MAKE NOTE OF THE TIME THE HEAT EXCHANGER IS FIRED, SHUT DOWN, COOLING WATER ADDED, AND ANY OTHER KEY TIME DURING CURING OPERATION.

[illegible]

Inspector's Checklist Sewer Sliplining (1 of 4)

INSPECTOR'S NAME _____

DATE _____ WEATHER _____

EST. HT. OF WATER TABLE ABOVE INVERT AT TIME OF INSPECTION _____

LOCATION OF SEWER

() AS-PAVT () FL-LAWN () DW-GRAV () SW-BTOP
 () BS-PAVT () RL-LAWN () DW-STOP () PW-PWAY
 () PC-PAVT () SL-LAWN () SW-CONC () UK-OTHER
 () GR-ROAD () DW-CONC () SW-BRCK DESCRIBE UK OTHER _____

M.H. NO. _____ to M.H. NO. _____ DISTANCE _____

TILE TYPE

() VT () C1
 () PL () ST
 () CO () OT
 DESCRIBE OTHER _____

TILE SIZE _____ IN DISTANCE BETWEEN JTS. _____
 AVE. FLOW DEPTH _____ IN. AVE. SEWER DEPT: _____ FT.

ROOT GROWTH	TYPE OF DEPOSITS	DEPTH OF DEPOSITS
() HEAVY	() GRAVEL () SLUDGE	_____ IN.
() MOD	() SILT () BITUMINOUS	
() LIGHT	() DETERGENT () MISC.	
() NONE	DESCRIBE MISC. _____	

TYPE OF CLEANING PERFORMED	Date _____	VISIBLE INFILTR/EXFILTR. SOURCES
() NONE () HIGH PRESS FLUSH		() ROOTS () SERVICES
() RODDING () ROOT CUTTING		() OFFSET JTS. () DETERIORATED
() BUCKETING () OTHER		() CRACKED TILE JT. MATERIAL
() OTHER (DESCRIBE) _____		() OTHER (DESCRIBE) _____

PRE-LINING INTERNAL INSPECTION VIDEO TAPE REF. NO. _____

PRE-GROUTING INTERNAL INSPECTION-VIDEO TAPE REP. NO. _____

JOINTS: () PULLED	PIPE: () SAGS
() OFFSET	() RADIAL CRACKS
() CRACKED	() LATERAL CRACKS
() ROOTS	() DEPOSITS
() INFILTRATION	() BROKEN PIPE
() EXFILTRATION	() BROKEN PIPE

PRE LINING VISIBLE: M.H. INFILTRATION; () YES () NO

SERVICES

NO. _____
 SIZE _____
 NO. ACTIVE _____

Inspector's Checklist Sewer Sliplining (2 of 4)

NO. INACTIVE _____
 SERVICE ROOTS _____
 NO. FACTORY WYES OR TEES _____
 NO. TAPS _____
 NO. OF PROJECTING TAPS _____
 NO. SERVICES REQUIRING DIG-UP PRIOR TO LINING _____
 REMARKS _____

METHOD OF BYPASSING (IF REQUIRED) _____

EQUIPMENT REQUIRED FOR BYPASSING _____

TIME AND DATE BYPASSING STARTED _____

TIME AND DATE BYPASSING STOPPED _____

TOTAL TIME OF BYPASSING _____

TIME AND DATE INDIVIDUAL SEWER SERVICE TERMINATED _____

TIME AND DATE INDIVIDUAL SEWER SERVICE REINSTATED _____

TOTAL TIME OUT OF SERVICE _____

TOTAL NUMBER OF SERVICES THIS SECTION _____

TRAFFIC CONTROL REQUIRED

() LANE CLOSURE NO. OF LANES _____	TOTAL TIME REQUIRED _____
() TOTAL STREET CLOSURE _____	TOTAL TIME REQUIRED _____
() FLAGMAN AND SIGNING ONLY _____	TOTAL TIME REQUIRED _____
() NONE _____	

REMARKS _____

ACCESS EXCAVATION FOR SLIP LINING

DIMENSION OF EXCAVATION AT THE SURFACE _____ WIDTH FT. x _____ LENGTH.

DEPTH OF EXCAVATION _____

DID ACCESS EXCAVATION REQUIRE ANY SHEET AND/OR BRACING? () YES () NO

IF YES EXPLAIN _____

HOW MUCH OF THE TOP OF PIPE WAS REMOVED FOR INSERTION OF THE LINER? _____ FT.
 WAS ANYTHING DONE TO REINFORCE THE LOWER HALF OF THE PIPE IN THE AREA OF INSERTION AFTER THE TOP HALF OF THE PIPE HAD BEEN REMOVED? _____

Inspector's Checklist Sewer Sliplining (3 of 4)

- () FLEXIBLE PULL HEAD
() RIGID PULL HEAD

WAS A PULL MADE IN BOTH DIRECTIONS FROM ACCESS EXCAVATION. () YES () NO
LENGTH OF FIRST PULL _____ FT. _____
LENGTH OF SECOND PULL _____ FT. _____

PHYSICAL PROPERTIES OF LINER PIPE

MFG. _____
OD _____ IN. ID _____ IN. WALL THICKNESS _____ IN.
SDR NO. _____

WAS THE ORIGINALLY SPECIFIED LINER PIPE USED? () YES () NO
IF NO, EXPLAIN WHY ALTERNATE LINER PIPE WAS USED _____

WAS THE ENTIRE LENGTH JOINED BY BUTT FUSION TECHNIQUE. () YES () NO
IF NO, EXPLAIN METHOD OF CONNECTING THE TWO LONG LENGTHS OF PIPE.

HOW LONG A PERIOD OF TIME WAS THE LINER ALLOWED TO REACH EQUILIBRIUM
FROM THE EFFECTS OF PULLING AND TEMPERATURE CHANGE? _____ HOURS
TOTAL LENGTH OF PIPE _____ FT.
CHANGE IN LENGTH OF PIPE _____ FT. (LONGER OR SHORTER)

SEALING LINER AT MANHOLE

DESCRIBE METHOD AND MATERIAL USED TO SEAL LINER AT MANHOLE _____

METHOD OF RECONNECTING EXISTING SERVICE CONNECTIONS.

() SADDLE () REMOTE TAPPING SYSTEM () OTHER

IF OTHER OR REMOTE TAPPING SYSTEM EXPLAIN METHOD USED _____

IF SADDLES WERE USED ON WHAT SIZE PIPE WERE SADDLES WITH A BOTTOM
HALF USED? _____

DESCRIBE MATERIALS USED, INCLUDING ANY ADAPTORS (TYPE) AND/OR
COUPLING (TYPE) USED TO RECONNECT SERVICES _____

DURING THE RECONNECTING OF THE EXISTING SERVICES WHAT WAS THE AVERAGE
LENGTH OF NEW PIPE LAID? _____ FT.

Inspector's Checklist Sewer Sliplining (4 of 4)

COST OF REHABILITATION

PREPARATORY CLEANING (INC. ROOT REMOVAL)	\$	_____
INTERNAL INSPECTION (PRE)	\$	_____
INTERNAL INSPECTION (POST)	\$	_____
BYPASS PUMPING	\$	_____
POINT REPAIRS	\$	_____
SLIPLINING CONTRACT (PIPE + LABOR + LATERAL CONNECT)	\$	_____
SURFACE RESTORATION	\$	_____
TOTAL	\$	_____

INSPECTOR'S GENERAL REMARKS. THIS SHOULD COVER ANY ITEMS WHICH THE INSPECTOR FEELS ADDED TO THE SUCCESS OF THE REHABILITATION, CAUSED PROBLEM DURING REHABILITATION OR WOULD BE HELPFUL TO THE REVIEWER IN EVALUATION OF THE REHABILITATION PROCESS AND RESULTS.

Inspector's Checklist Point Repairs (1 of 3)

INSPECTOR'S NAME _____
 CONTRACTOR'S NAME _____
 DATE _____ WEATHER _____

EFFECT OF WEATHER _____

LOCATION _____

EST. HT. OF WATER TABLE ABOVE INVERT AT TIME OF INSPECTION _____

LOCATION OF SEWER

() AS-PAVT () FL-LAWN () DW-GRAV () SW-BTOP
 () BS-PAVT () RL-LAWN () DW-STOP () PW-PWAY
 () PC-PAVT () SL-LAWN () SW-CONC () UK-OTHER
 () GR-ROAD () DW-CONC () SW-BRCK DESCRIBE UK OTHER _____

M.H. NO. _____ to M.H. NO. _____ DISTANCE _____

M.H. REHABILITATION (IF ANY)

M.H. No.	DIA.	DEPTH	MATERIAL	TYPE OF REPAIR
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

TILE TYPE

() VT () CI
 () PL () ST
 () CO () OT
 DESCRIBE OTHER _____

TILE SIZE _____ IN DISTANCE BETWEEN JTS. _____

AVE. FLOW DEPTH _____ IN. AVE. SEWER DEPT: _____ FT.

ROOT GROWTH	TYPE OF DEPOSITS	DEPTH OF DEPOSITS
() HEAVY	() GRAVEL () SLUDGE	_____ IN.
() MOD	() SILT () BITUMINOUS	
() LIGHT	() DETERGENT () MISC.	
() NONE	DESCRIBE MISC. _____	

TYPE OF CLEANING Date _____
 PERFORMED

() NONE () HIGH PRESS FLUSH
 () RODDING () ROOT CUTTING
 () BUCKETING () OTHER
 () OTHER (DESCRIBE) _____

VISIBLE INFILTR/EXFILTR.
 SOURCES

() ROOTS () SERVICES
 () OFFSET JTS. () DETERIORATED
 () CRACKED TILE JT. MATERIAL
 () OTHER (DESCRIBE) _____

COMMENTS _____

Inspector's Checklist Point Repairs (2 of 3)

_____ BYPASSING REQUIRED () Y () N
 DATE _____
 REASON IF YES _____
 PERIOD OF BYPASSING: FROM _____ TO _____
 TOTAL TIME OF BYPASSING _____
 METHOD OF BYPASSING _____
 EQUIPMENT REQUIRED _____
 TIME AND DATE INDIVIDUAL SEWER SERVICE TERMINATED _____
 TIME AND DATE INDIVIDUAL SEWER SERVICE REINSTATED _____
 TOTAL TIME OUT OF SERVICE _____
 TOTAL NUMBER OF SERVICES THIS SECTION _____
 WAS EXISTING UTILITY RELOCATION NECESSARY () Y () N
 IF YES EXPLAIN _____

TRAFFIC CONTROL
 () LANE CLOSURE NO. OF LANES _____ TOTAL TIME REQUIRED _____
 () TOTAL STREET CLOSURE _____ TOTAL TIME REQUIRED _____
 () FLAGMAN AND SIGNING ONLY _____ TOTAL TIME REQUIRED _____
 () NONE
 REMARKS _____

PRE-REPAIR - INTERNAL INSPECTION VIDEO TAPE REF. NO. _____
 JOINTS: () PULLED PIPE: () SAGS
 () OFFSET () RADIAL CRACKS
 () CRACKED () LATERAL CRACKS
 () ROOTS () DEPOSITS
 () INFILTRATION () BROKEN PIPE
 () EXFILTRATION

PRE-REPAIR - VISIBLE M.H. INFILTRATION () YES () NO
 SERVICES
 NO. _____ NO. TO BE REPLACED _____
 SIZE _____
 NO. ACTIVE _____ NO. INACTIVE _____
 SERVICE ROOTS _____
 NO. FACTORY WYES OR TEES _____ NO. TAPS _____
 NO. OF PROJECTING TAPS _____

POINT REPAIR; () WET () DRY
 NO. OF REPAIRS _____ TOTAL LENGTH _____
 STA. TO STA. _____
 PIPE SIZE _____ PIPE TYPE _____ DEPTH _____
 TOTAL CONCRETE USED _____ C.Y. NO. POINTS ENCASED _____
 TYPE OF BEDDING _____ QUANTITY USED _____
 TYPE OF BACKFILL _____ COMPACTION _____
 QUANTITY OF ADDITIONAL BACKFILL MATERIAL _____
 TYPE OF EQUIPMENT _____

Inspector's Checklist Point Repairs (3 of 3)

TIME AND DATE STARTED _____

TIME AND DATE STOPPED _____

TOTAL TIME _____

TYPE OF SOIL _____ WIDTH OF TRENCH _____

SHEATING (IF REQ'D) _____ SQ. FT. LEFT-IN-PLACE

REPAIRS TO MANHOLE _____

() ADDITIONAL T.V. (IF REQ'D)

COST OF REHABILITATION

INTERNAL INSPECTION (PRE)	\$ _____
INTERNAL INSPECTION (POST)	\$ _____
BYPASS PUMPING	\$ _____
POINT REPAIRS	\$ _____
TEST LINE	\$ _____
SURFACE RESTORATION	\$ _____
TOTAL	\$ _____

INSPECTOR'S GENERAL REMARKS. THIS SHOULD COVER ANY ITEMS WHICH THE INSPECTOR FEELS ADDED TO THE SUCCESS OF THE REHABILITATION, CAUSED PROBLEM DURING REHABILITATION OR WOULD BE HELPFUL TO THE REVIEWER IN EVALUATION OF THE REHABILITATION PROCESS AND RESULTS.

APPENDIX E:

SPECIFICATION TO INCORPORATE FLEXIBLE COUPLINGS IN SLIPLINING METHODOLOGY

This appendix lists the subsections relevant to flexible couplings from the NAVFACENGCON specification for sliplining, Section 02727. Sentences specifically applying to flexible couplings are underlined.

The concept of an expansion joint has been to the point of a specification by Kenneth Morin of the Chesapeake Division, Naval Facilities Engineering Command, based on a technique developed at Napa Valley (California) by Richard Shank of the Napa Sanitation District. The technique involves excavating at each manhole to expose an 18-inch stub of the existing sewer pipe, and installing a flexible coupling to seal the connection and prevent inflow at the manholes. The specifications relating to the flexible coupling installation (Subsections 2.1.1.4, 3.1.2 and 3.1.9) from Section 02727 are as follows. Items pertaining to the use of the flexible coupling are underlined.

2.1.1.4 Flexible Coupling: The coupling shall be fabricated from flexible PVC conforming to ASTM C 425, C 443, C 564 and D 1869. The clamps including the band, screw and housing shall be fabricated of 300 stainless steel.

These specifications can be incorporated into existing Corps of Engineers specifications, changing the numbers and reference sections, to incorporate this infiltration control technique into Army renovation. Figure XX is a schematic diagram of the installation procedure. POC for further information on this process is Kenneth Morin, COMM 202-433-3760, AV 288-3760.

3.1.2 Excavation: Excavation shall be in accordance with Section 02225, "Excavation, Backfilling, and Compacting for Utilities." Excavate at each building service connection to the main, through which sliplining pipe is to be installed, after insertion of the liner pipe into the existing sewer. Provide access shaft excavations on the upstream and downstream manhole. Saw cut a section out of each end of the existing sewer leaving an 18-inch stub from the section out of each end of the existing sewer leaving an 18-inch stub from the upstream and downstream manhole. The end of each stub must be cut squarely. A flexible coupling with clamps shall be placed on each stub. The liner shall be inserted into the existing sewer from either access shaft.

3.1.5 Insertion of the Liner: Insertion shall be in accordance with ASTM F 585. The top of the existing main shall be exposed to springline for the full length of the access shaft prior to removal of the crown portion of the existing main. A power winch shall then be connected to the end of the liner by use of the pulling head, so the liner can be inserted into the existing sewer. Precautions shall be taken not to damage the liner or break any joints. At each 18-inch stub, the power head shall be removed if necessary and the liner pushed through the flexible coupling until it sticks approximately halfway into each manhole. The flexible coupling used shall be sized so that the inside diameter of the coupling's stub end equals the outside diameter of the stub and the inside diameter of the couplings slipliner and equals the outside diameter of the slipliner. Sliplining through a manhole is prohibited.

3.1.5.1 Passing the Liner through the flexible coupling: If necessary the contractor shall shave the interior wall of the flexible coupling reducing its wall thickness by as much as 1/8 inch to facilitate the liner passing completely through the coupling. A lubricant (e.g. soapy water) poured over the liner may also be used to facilitate the liner

going through the coupling. The liner must pass through the coupling and continue through to the manhole. If a liner does not pass through the coupling and continue through the upstream pipe stub and is only connected to the stub by the flexible coupling the transition in the coupling between the stub and the liner will force the sewage to flow uphill. This transition may result in solids settling out. This type of connection is not acceptable. Getting the liner through the flexible coupling to the manhole is critical to avoid creating a blockage problem at the coupling.

3.1.5.2 Connection of Flexible Coupling at an Outside Drop Manhole: The flexible coupling shall be secured to a stub located approximately 18 inches upstream of the drop. To eliminate the need for reconnection of the outside drop to the liner, the liner shall terminate at the coupling.

3.1.5.2.1 Connection of the Flexible Coupling to the Stub: The entire length of the 18 inch stub must be exposed prior to attaching the coupling. If a spigot end of a pipe is available, remove the existing pipe to the spigot and attach the coupling.

3.1.6 Stabilization of Liner: The polyethylene liner may contract after insertion because of residual stresses imposed during pulling, and thermal stresses from temperature differences between the liner and sewer. Residual stresses shall be relieved by pushing or pounding of the end of the liner at the entrance pit until the tension at the winch is relieved. The liner shall be allowed to stabilize 16 hours at the sewer temperature before cutting or grouting the annular space at the manholes and before fully tightening and backfilling the flexible couplings at each end of the liner.

3.1.9 Access Excavation and Pipe Stub Encasement: If the stub, on which the flexible coupling is to be attached, is found to be in poor condition, the stub shall be encased in concrete after the liner has passed through the coupling and the coupling has been secured. The bottom of the concrete encasement shall rest on undisturbed ground. The encasement shall be 3000 psi concrete, a minimum of 6 inches thick. Backfill shall be as specified in Section 02225, "Excavation, Backfilling, and Compacting for Utilities".

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Letterkenny Army Depot 17201
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HQDESCOM Letterkenny Army Depot 17201
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Scranton Army Ammo Plant 18505
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HQ, First U.S. Army 20755
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Port Story 23459 ATTN: ATZF-FE	Lima Army Ammo Plant 44266 ATTN: SMCRV-O	Pine Bluff Arsenal 71602 ATTN: SMCPB-FA
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Fort Monroe 23651 ATTN: ATZG-EH	Jefferson Proving Ground 47250 ATTN: STEJP-LD-F	Fort Sill 73503 ATTN: ATZR-E
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Fort Pickett 23824 ATTN: ATZM-FPE	Newport Army Ammo Plant 47966 ATTN: SMCNE-EN	Red River Army Depot 75501 ATTN: SDSRR-AF
Redford Army Ammo Plant 24141 ATTN: SMCRA-EN	TACOM Support Activity 48045 ATTN: AMSTA-XYN	Lone Star Army Ammo Plant 75505 ATTN: SMCLB-EN (2)
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Fort Jackson 29207 ATTN: ATZJ-EH	U.S. Army Tank Automotive Command Facility Division, Detroit Arsenal 48397 ATTN: AMSTA-XE	III Corps and Ft. Hood 76544 ATTN: AFZP-DE CMD
Fort Gillem 30050 ATTN: AFZK-G-FE	Badger Army Ammo Plant 53913 ATTN: SMCBA-OR	Fort Hood 76544 ATTN: AFZE-DE
Fort McPherson 30330 ATTN: AFZK-EH	Fort McCoy 54656 ATTN: AFZR-FE	Ft. Sam Houston 78234 ATTN: AFZG-DE
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Fort Benning 31905 ATTN: ATZB-EH	Joliet Army Ammo Plant 60436 ATTN: SMCJO-EN	Rocky Mountain Arsenal 80022 ATTN: SMCPM-ISF
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